AN APPLICATION OF SIMULATION NETWORKING TECHNIQUES IN OPERATIONAL TEST DESIGN AND EVALUATION

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AN APPLICATION OF SIMULATION NETWORKING TECHNIQUES
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Approved:

Douglas C. Montgomery, Chairman

Russell G. Heikes

I. Gayden Thompson

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SUMMARY

Operational tests are a subactivity of the total material acquisition development cycle. They contain within this subactivity a number of additional activities, subtests, or subprograms. Each of these activities or subtests has related functional values. These values may be deterministic, stochastic, or some mathematical transformation of a value computed in an earlier activity. These activities lead to milestones or events and the outcome of the operational test can be represented by a set of successful and a set of unsuccessful events. This set of conditions describes a stochastic network. Of the network analysis tools, network simulation affords the greatest versatility and flexibility in modeling this set of conditions. Of the family of network simulation programs two programs have evolved as useful analysis tools to assess risk, SOLVNET and VERT.

VERT's extensive output, redimensioning capability, flexible node logic, extensive number of probability distributions, and mathematical transformations and simultaneous accumulation of the three principal dimensions of time, cost, and performance into the "fourth dimension" risk make it the best choice for modeling extensive problems in a decision environment. SOLVNET is better suited to problems in the time/cost plane which are characterized by extensive

dependency interactions.

The extension of this concept to the conduct of risk analysis in the design and conduct of an operational test is both feasible and practical. A network analysis tool such as VERT "removes the inductive headaches from modeling component interaction. These operands enable the user to explore conditional nonlinear multivariate situations which defy ready mathematical analysis" [34]. Test plans and designs fall neatly in line with little manipulation of these operands in building a model to assess test design risk. The use of a formalized tool to assess risk would generate interest among the test designers and evaluators in analyzing data inputs. During the course of the analysis:

1. Potential problems can be identified.
2. The risk consequences of a subtest failure can be assessed.
3. Low impact tests can be identified.
4. High impact tests can be identified.
5. The sufficiency of test projections for time, cost, and associated performance allocations can be determined.

In summary, the objective of a risk analysis study in operational testing is to create a model of the operational test and exercise the model with realistic inputs. The results of this analysis provide the operational test decision-maker with a basis to compare competing test alternatives.

CHAPTER I

INTRODUCTION

Risk Analysis Background

Although the terminology and the techniques for risk analysis are not new, the interest of former Deputy Secretary of Defense David Packard in his memoranda issued on 31 July 1969 [12] and 28 May 1970 stirred considerable interest in the application of these techniques to the acquisition of major weapons systems for the Department of Defense. From the numerous approaches, definitions, models, and techniques which surfaced during the early 1970's the central theme seemed to be that although the precise definition of <u>risk analysis</u> is unclear, it is a part of systems analysis and differs from the more specific procedure <u>decision analysis</u>. A condensation of the literature applicable to illustrate these points will be outlined in the first part of Chapter II.

Since risk analysis is neither an art nor a science, one must choose a definition on which to base his analysis. The theme of this thesis is to develop risk analysis procedures applicable to operational testing; hence, throughout the remainder of this thesis, the term <u>risk</u> is the probability that an operational test will not be completed within specified time, cost, and performance constraints. Risk assessment is the quantification of this uncertainty and risk analysis, simply stated, is the risk associated with alternatives of test design, data collection, and data analysis. Risk analysis provides the operational test decision-maker with a tool to assess the criticality of test data and the uncertainty in the design.

To aid the decision maker in risk analysis a number of tools are available to assist in the procedure. Since each test design is unique and the data availability for certain designs questionable, all, part, or some combination of techniques may be used. Among these are subjective probability estimation such as the Delphi technique, Monte Carlo simulation, network analysis, and Bayesian statistical inference.

Network Analysis

In this thesis network analysis has been selected as the tool most likely to contribute significantly to the decision-maker's assessment of risk in operational testing. The fundamental reason is that it provides the most logical combination of all available tools into a total risk assessment procedure and provides ease in modeling operational test designs. It also provides a means for specifying data requirements and evaluates their impact on the test design.

Although no automatic system is available to allow the analyst to build a network model of a unique test design, several analytical techniques and computer programs are available to assist the analyst in the conduct of an evaluation of the network. A background of network analytical methods and more specifically network simulation will be presented in the last part of Chapter II. Of the available network simulation programs, two programs are referenced most extensively in the literature and appear to be useful to the analyst in assessing the risk in operational testing; Venture Evaluation and Review Technique (VERT) and SOLVNET.

VERT was written and programmed by Gerald Moeller, United States Army Armaments Command Rock Island, Illinois, in 1972 and offered as a standard Fortran IV program for Department of Denense for use in network analysis. SOLVNET was written and programmed by Stephen R. Pearcy, United States Army Armaments Command, Picatinny Arsenal, Dover, New Jersey, in early 1973. Although written by agencies of the United States Army Materiel Command and taught in the United States Army Logistics Training Center, Fort Lee, Virginia, they are not in wide use throughout the command or specified for use in risk assessment in regulations of that command. A comparison of the two Fortran programs and their applicability to risk analysis will be presented in Chapter III, and an integration of network simulation into test design and evaluation will be discussed in Chapter IV. The heart of the thesis will be the application and analysis of data in a test design model of an Army Air Defense System in Chapter V.

Purpose and Scope

The purpose of this thesis may be summarized as follows:

1. Review and analyze network simulation as a viable risk analysis technique for operational testing.
2. Compare two existing computer programs available to conduct network simulation.
3. Apply network simulation to an operational test design illustrating the criticality and sensitivity of test design data.

Operational or user-oriented testing is an essential part of the material development cycle for government and industry. Inherent in the conduct of these tests is the uncertainty that the proposed test design will fail to meet time and cost schedules without degradation of performance standards. The decision-maker has a need to know the effect that changes in data inputs, test design, or test limitations have on the risk. The results of this research should provide interested agencies with a means to assist test designers and evaluators with the quantification of risk and the conduct of risk analysis. The network modeling techniques used in the conduct of this research should be typical of those encountered in the general problem of operational test design and evaluation. It is felt that these procedures will add in some way to the knowledge of network analysis methodology.

CHAPTER II

LITERATURE REVIEW

Risk Analysis

The concept of decision-making under uncertainty is not new. It has been studied and reported in the early statistical literature by Pascal, Bernoulli, and Bayes in the 17th and 18th century. Most applications were limited to games of chance and related phenomenon. Until the recent upsurge in scientific approaches to management, frequently labeled systems management or systems analysis, real world problems were not seriously considered. The increasing costs of resources brought to bear a need to make management decisions on some quantified basis in lieu of the manager's intuition. This resource squeeze has placed increased reliance on systems analysis. Systems analysis has been defined [46] as a systematic approach to help a decision-maker to choose a course of action by investigating the problem, searching out alternative routes, and comparing them in the light of their consequence under an appropriate framework to bring expert judgment and intuition to bear on the problem, without violating exogenous constraints imposed on the problem under study. In light of this definition, Hwang [23] does not separate risk analysis from systems analysis but labels it a "fourth dimension" under which to effect tradeoffs. Risk analysis then is a part of systems analysis.

Prior to Deputy Secretary for Defense David Packard's memoranda directing the military departments to institute formal risk analysis [12], the terms risk, risk averse, or risk analysis were largely associated with actuarial science and investment analysts. Some references also associate a psychological state of a manager as risk averse. In fact, a large body of management literature concerning utility theory relies on this assumption.

The Army Materiel Systems Analysis Agency, United States Army Materiel Command, Aberdeen, Maryland [2] differentiates decision analysis as defined by Raiffa [47] from risk analysis. Risk analysis provides an orderly comprehensive analysis of alternatives highlighting the uncertainty in the decision. Decision analysis utilizes the decision-maker's preference in selecting an alternative. Decision analysis relies heavily on utility theory and although Hwang [22] has outlined a model for risk analysis using military utility in the materiel acquisition process, determining a utility function for this process is difficult because of the lack of comparative measures similar to profit and loss in the industrial community. Howard [21] discusses the development of decision analysis in recent business and government applications with no solution to the lack of comparative measures discussed by other authors.

Prior to 1969 risk assessment in the military materiel acquisition decisions was largely the subjective judgment of the decision-maker or his staff analyst [52]. Simplistic deterministic models were proposed by Varnell *et al*. [52], Shear [48], and Hwang [23], but their application is limited to projects with little complexity. A similar quantitative procedure is proposed for test designers and project managers of the United States Army Test and Evaluation Agency, United States Army Materiel Command, Aberdeen Proving Ground, Maryland, in their most recent USATECOM pamphlet 70-5 [51]. These models provide a methodology for the manager to assess risk, and as pointed out by the United States Air Force Risk Analysis Study Team [50], "There is no 'one best way' to conduct a risk analysis." From their exhaustive literature survey in 1970 one could not argue with their conclusion. They found it difficult to find a reasonably clear definition of risk analysis and it is essentially their definition, "risk is the probability that a project will not be completed within a specified time, cost and performance constraints by following a specified course of action" that will be used in this thesis. Since their study in 1970 and using the foundations laid in 1962 and 1966 by Eisner, Pritsker, Happ, and Whitehouse [13, 44, 53] network simulation has been extensively developed. This may be the most effective way to conduct risk analysis for large complex models.

Network Analysis

The success of the United States Navy in 1958 using PERT (Program Evaluation and Review Technique) in the development of the Polaris Fleet Balistic Missile System generated a substantial body of network analysis methodology. PERT was originally designed to be time-oriented and did not directly consider cost or availability of resources. PERT time durations are subject to a probability distribution. An integral part of this distribution are three time estimates--normal, optimistic, and pessimistic. The assumption of a beta distribution has drawn considerable comment in the literature. Malcolm *et al.* [31], Murray [37], MacCrimmon and Ryavec [41, 42], Clark [6], Grubbs [18], and Hartley and Wortham [19] are among those who have discussed the PERT assumptions and suggested alternatives. Some extensions of PERT include PERT/Cost [39] and PERT/Reliability [32]. PERT/Cost adds resource cost to the normal PERT/Time schedule. It does not attempt to use cost data to optimize total cost and provides no probability information on cost data. PERT/Reliability is an extension of PERT into reliability management.

CPM (Critical Path Method) was developed independently at the same time as PERT for a construction project at DuPont. This method was instituted by Kelly and Walker [25, 26, 27], developed further by Fulkerson [16], and refined by Moder and Phillips [49, p. 109]. CPM requires that time durations be deterministic for a certain level of resource utilization. CPM has been extended to CPM/Time by Gessford [17] and "make" or "buy" decisions by Kleinshmidt, Moore, and Tamashanas [28].

PERT and CPM program planning and control methods have been used extensively in research and development scheduling, construction planning, and resource allocation models [11]. In 1966 Pritsker and Happ [44] attributed the increasing rate of networks and network analysis to the ease with which operational systems could be modeled in network form. They also attributed the growth to (1) the ability to model complex systems by compounding simple systems, (2) the need for a communications mechanism to discuss the operational system in terms of its significant features, (3) a means for specifying the data requirements for analysis of the system, and (4) a starting point for analysis and scheduling of the operational system.

In view of the complexity associated with risk analysis for Department of Defense military departments, it is not difficult to understand why the military analyst has turned to network methodology. Bryant [4] lists a number of questions which can be brought to bear using network analysis: (1) How can one better allocate resources between activities to shorten the project, reduce risk, or reduce costs? (2) How can performance requirements be reduced in critical or pacing activities without greatly reducing the benefits of the program? (3) Are there non-critical activities where costs or risks can be reduced with no increase in the length of the overall program? (4) Is there a better network leading to a better combination of program time, cost, and performance values?

The first significant development to expand the capability of network models to incorporate more stochastic flexibility was the "decision box" introduced by Eisner [13]. Elmaghraby [19] added additional logic and algebra to network models and a number of authors have used flow-graphs to represent and analyze probability systems. The major development was Pritsker's Graphical Evaluation and Review Technique (GERT) [44]. Whitehouse [53] describes GERT as a procedure which combines the disciplines of flow-graph theory, moment generating functions, and PERT to obtain solution to stochastic problems. GERT derives both the probability that a node will be realized, and the conditional moment generating function of the elapsed time required to traverse between any two nodes.

Another method for evaluating stochastic decision models was proposed by Hespos and Strassmann [20] when they introduced the concept of the stochastic decision tree. They applied Monte Carlo and GPSS simulation techniques to conduct a risk analysis on investment decisions. Crowstone and Thompson [7] extended Eisner's decision alternatives into a CPM network. Their method became known as decision CPM.

The essential difficulty in applying the techniques outlined above to risk analysis is in the aggregation of a total risk profile. Stochastic networks are characterized by their events (nodes) and activities (arcs). When all activities leading to an event must be completed prior to the event taking place, the network node logic is labeled "AND". The aggregation of a total risk profile by PERT would require the construction of a network of only AND nodes with deterministic output where individual activity risk profiles were obtained from beta or triangular distributions. Similarly, the aggregation of a total risk profile by GERT would specify a case where all nodes have OR inputs and probabilistic outputs. OR logic specifies that only one activity leading to an event need be completed prior to the event taking place. Such a network is an extremely special case and one not likely to occur in practice. For models which do not fall naturally into either one of these categories, the natural way to accumulate a total risk profile is through network simulation.

In view of the lack of such special networks and the heavy emphasis of Secretary Parkard on risk analysis, the logistics training activity of the Army Materiel Command, The U.S. Army Logistics Management and Training Center (ALMAC) let a contract to Mathematica of Princeton, New

Jersey to develop a teaching aid for network simulation for logistics students. They developed a program known as MATHNET [33]. MATHNET was modified by the center to a smaller version called RISCA (Risk Information System and Cost Analysis) [1]. An expanded version for use by research and development managers was programmed by Stephen Percy, U.S. Army Armaments Command, Picatinny Arsenal, Dover, New Jersey and labeled SOLVNET [43]. An independent effort to build a risk analysis tool for use by the same group of managers in DOD and industry culminated in a network simulation program entitled VERT (Venture Evaluation and Review Technique) [35]. VERT has evolved from an expanded version of MATHNET known as STATNET.

A description, discussion, and comparison of VERT and SOLVNET follows in Chapter III. These network simulation programs have overcome many of the limitations of PERT, CPM, and GERT by offering both probabilistic and deterministic logic elements. With these network techniques the analyst can focus his attention on the accuracy of the inputs and leave the outcome of the model to the network methodology. The aggregation of time, cost, and performance parameters by simulation provides an analysis not possible under existing quantification techniques.

CHAPTER III

A DISCUSSION, DESCRIPTION, AND COMPARISON OF VERT AND SOLVNET

Networks and Network Simulation

A generalized network may be defined as a set of nodes, directed arcs, and functions assigned to those arcs. A node is characterized as an event or milestone. Directed arcs are typically activities or subprograms and the functions assigned to those activities may be deterministic or probabilistic relationships among known parameters.

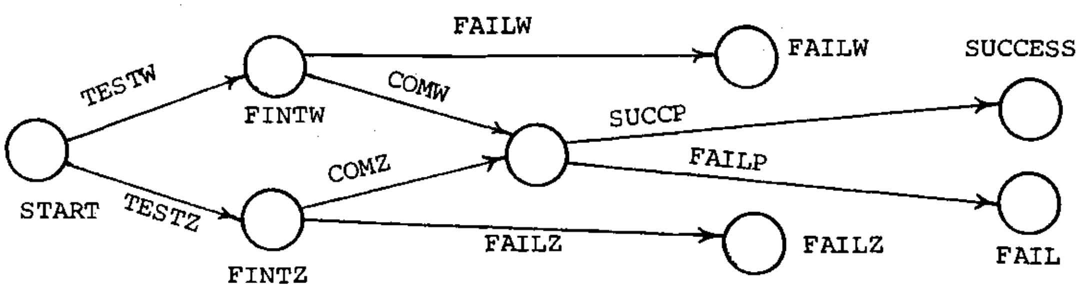


Figure 1. Network Test Diagram

Example

The U.S. Army Operational Test and Evaluation Agency (OTEA) has been asked to construct an operational test to compare the Wight and the Zamo. Wights and Zamos must meet minimum performance standards of 10 zaps per round. If both the Wights and Zamos meet minimum standards the system with the most zaps per round during the operational test will be selected. OTEA is limited to one week and $100 to test these new systems. The commander of OTEA is interested in conducting a risk assessment and risk analysis on this project.

Figure 1 represents a network model of this example. The nodes mentioned above are labeled START, FINTW, COMPT, FINTZ, FAILZ, FAIL, and SUCCESS. They represent events of interest to the test designer. For example, FINTW represents the completion of the data sampling of the operational test on the Wight. The remainder of the node labels are described in Table 1. Similarly, directed arcs are also indicated on the example network graph. They represent activities or sub-tests leading from one event to another event. For example, TESTW is the collection of hit data for the Wight. TESTW originates from the node START and is directed to the node FINTW. A complete listing of arcs is given in Table 2. The time to conduct the operational test and collect the hit data on the Wight (arc TESTW) is estimated to be normally distributed with a mean of one-half week and a standard deviation of one-fourth week. The Wight has previously demonstrated that its number of zaps per round is triangularly distributed with a mean of 12 between minimum and maximum zaps per round of 5 and 15. The cost to run the Wight test is linked to the amount of time necessary to conduct the test by a factor of $10.00

Table 1. Node Descriptions

Node	Description
START	Start point for the network
FINTW	Completion of data collection for the Wight System
FINTZ	Completion of data collection for the Zamo operational test
FAILW	Failure of the Wight System Test
FAILZ	Failure of the Zamo System Test
COMPT	Selection of the best system
Success	Termination of project
FAIL	Failure of project

Table 2. Arc Descriptions

Arc	Description
TESTW	Collection of hit data on the Wight System
TESTZ	Collection of hit data on the Zamo System
FAILW	Transportation arc for Wight failure
FAILZ	Transportation arc for Zamo failure
COMW	Compare Wight System GT 10 hits
COMZ	Compare Zamo System GE 10 hits
SUCCP	Transportation arc for project success
FAILP	Transportation arc for project failure

times the test duration in weeks. These are examples of the functions which are assigned to arc TESTW. Note that number of zaps per round and amount of time necessary to conduct the test are probabilistic while cost is deterministic. The remaining functional relationships assigned to the arcs are outlined in Table 3.

Table 3. Arc Functions

Arc	Parameter	Distribution	Mean	SD	Min	Max
TESTW	Time	Normal	1/2	1/4		
	Performance	Triangular	12		5	15
	Cost	None	$10 x Time			
TESTZ	Time	Normal	1/2	1/4		
	Performance	Erlang	13		8	18
	Cost	None	$15 x Time			
COMW	Time	Exponential	1/2		0	1
COMZ	Time	Exponential	1/2		0	1

Note: FAILW, FAILZ, SUCCP, and FAILP are transportation arcs with no function assignment but with a probability of initiation.

Stochastic networks have the additional following characteristics:

1. Nodes depict logical operations.
2. Each arc has associated with it the probability that it will be performed.
3. A realization of the network is a particular set of arcs and nodes which describes the network for one experiment.

4. If a parameter is a random variable, realization of the network implies that a fixed value for that parameter has been selected for each arc [49].

The ability of a stochastic network to represent the real world then lies in the flexibility associated with node logic. Each node must be defined by a set of input arcs and a set of output arcs, hence, each node must have a specified input logic and corresponding output logic. The basic types of input logic to a stochastic network are AND and OR, and the basic output logic is DETERMINISTIC or PROBABILISTIC. Table 4 summarizes a description of these types of node logic.

Table 4. Basic Logic Descriptions

Logic	Description
Input:	
AND	All arcs entering the node must be realized before the node is realized
OR	The node is realized when the first arc entering it is realized
Output:	
DETERMINISTIC	All arcs emanating from the node are initiated when the node is realized
PROBABILISTIC	Arcs emanating from the node are realized when the node is realized according to a specified probability distribution

Each node then is a composite of input and output logic portions. Figure 2 is an example of a AND/DETERMINISTIC split node.

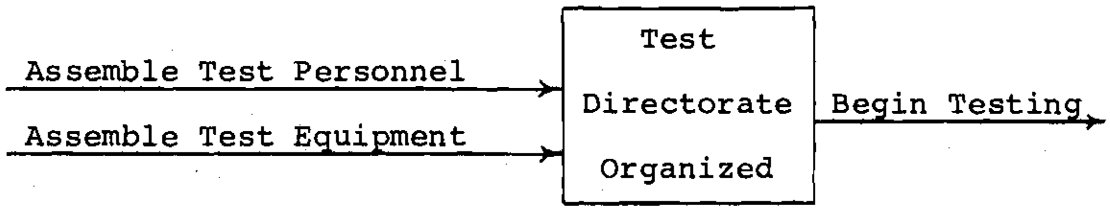


Figure 2. AND/DETERMINISTIC Split Node

Here both the assemble test personnel arc and the assemble test equipment arc must be completed successfully before the node Test Directorate Organized is realized. Arc Begin Testing is initiated when the input rule for the node is satisfied. Figure 3 illustrates OR/PROBABILISTIC split node logic.

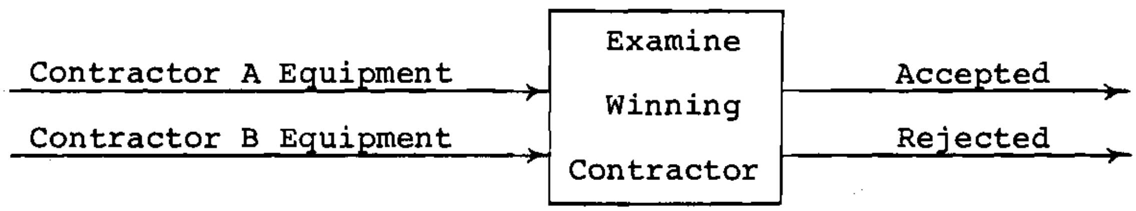


Figure 3. OR/STOCHASTIC Split Node

In this example, only the equipment of one contractor will be examined. The winning arc could be based on a computation and weighted comparison of minimum time, maximum performance, and minimum cost, some function of risk, or a function of other relevant parameters. The initiation of either accepted or rejected arcs follows a probability distribution.

The four combinations of basic input and output logic will be required to complete flow within a network and more closely approximate the real world. It also follows that all arcs within the network need not be realized in order to realize the terminal node of the network. Arcs emanating from a probabilistic node may not be realized and arcs entering a node with OR input logic may be unsuccessful.

Once the analyst has formulated his model and developed the individual functions represented by each arc or activity, he must select a method to aggregate or collect his individual relationships into a total profile for the parameter he is interested in analyzing. Among the network analysis methods he may use are GERT, PERT, CPM, and network simulation.

GERT is limited to networks consisting of nodes with OR input logic and probabilistic output logic. Pritsker's technique uses the moment generating function from the parameter profile on each branch to develop a total parameter profile for the network. Since risk is of interest here, such a profile may be risk versus time or risk versus cost. A total OR/PROBABILISTIC network is extremely unlikely.

Another technique that the analyst can turn to is PERT. PERT would require a total AND/DETERMINISTIC node logic network whose functions were beta or triangular. Similarly, a total AND/DETERMINISTIC network with beta or triangular distributions is unlikely. CPM requires entirely deterministic logic. Consequently, it seems that the only practical way to assemble a total profile is through network simulation.

Network simulation accumulates a total profile by iteratively computing and selecting values from each of the arcs on successive passes through the network. If time versus risk is of interest, network simulation will compute values based on individual arc time versus risk profiles on the first pass through the network and aggregate them into a time versus risk value. The next iteration would compute another time versus risk value and hence, develop a total time versus risk profile. It is a powerful technique which will allow combinations of probability and deterministic values which would defy ananlytical computation. Since considerable computational effort is required, network simulation is limited to computer applications. The process actually consists of the analyst restricting his model to the class capable of being modeled by existing network simulation programs. Thus, the quality of network simulation is limited only by resources available for the effort. SOLVNET and VERT are examples of excellent network simulation programs which are available to the analyst to exercise his model. They are typical of the programs available and have been selected for further analysis in this thesis.

SOLVNET

SOLVNET was written and programmed in Fortran IV by Stephen Percy in January 1973. SOLVNET was designed to extend the capability of MATHNET so that a more complete and accurate analysis could be performed. Network structure and input/output format to SOLVNET are patterned after MATHNET so that users who were trained on a version of MATHNET known as RISCA could easily transition to the more extensive network logic program.

As background MATHNET was developed by Mathmatica, Princeton, New Jersey for use by the U.S. Army Logistics and Training Center (ALMAC), Fort Lee, Virginia. ALMAC is charged with the responsibility to train Army materiel project managers and analysts in the fundamentals of risk assessment and risk analysis among other logistics matters. RISCA(Risk Information System and Cost Analysis) is a revised MATHNET with improved output format. Since they are essentially the same, the more extensive SOLVNET was chosen as the program to be discussed from this family of programs.

SOLVNET is designed to allow one to analyze stochastic networks. Since arc times and/or costs can be modeled probabilistically, Monte Carlo procedures are used to determine the path or activity value of a random variable at each iteration. Repeated iterations develop a sampling distribution for terminal events (Network Simulation).

SOLVNET is essentially a two-parameter network analysis technique. It has been designed to develop the time distribution of a developmental project with multiple stochastic or deterministic activities which may be interdependent or independent. The cost distribution of a project can also be developed independent of time by performing a separate simulation, or estimated as a linear function of time in the same simulation; i.e., cost = (fixed cost) + (variable cost) x (time).

SOLVNET arcs are represented by a name, the name of the initiating node, the name of the terminating node, and the probability of the arc being successful once it has been initiated. The cost associated with this arc can be entered as a fixed cost component and a linear (with respect to time) cost component, or as any distribution of cost related to time in cumulative distribution form. Arc completion times may be normally, triangularly, or uniformly distributed. If none of these distributions are applicable any probability distribution in cumulative distribution form may be used. SOLVNET arc's time and cost computations may be dependent on the realization of its terminal node. Its time and probability of success may also be dependent on the results of another arc or node.

A description of SOLVNET node logic is outlined in Table 5. There are three basic input rules and three basic

Table 5. SOLVNET Node Logic Description

Logic	Description
	Input Split Node
INITIAL	Possesses no input arcs, used as a start point for the network. (A network may have more than one starting point.)
AND	Requires all arcs entering this node to be successfully completed before the node is realized.
OR	Only one arc must be successfully completed before the node is realized. If more than one input arc is successful the arc with the earliest completion time satisfies the node.
	Output Split Node
TERMINAL	Used to represent a completion point of the network.
ALL	All arcs will be simultaneously initiated when the input rule has been satisfied.
STOCHASTIC	When the input rule has been satisfied, one output arc will be initiated on a stochastic basis. All output arcs have been assigned a probability of initiation.
	Special Linked Input/Output
1/1 BAR	N input arcs and N + 1 output arcs. The N + 1st arc is the default arc. OR input logic prevails.
Preferred	1/1 Bar format except that instead of the first successfully completed arc satisfying the input rule, the most preferred arc that is completed successfully satisfies the input rule.

Table 5. Continued

Logic	Description
USER DEFINED	Permits the user to define the input and output rules in terms of successful or unsuccessful combinations of input arcs.
USER DEFINED PREFERENCE	Same format as the User Defined node with added feature of a preference order.

output rules for split logic nodes. In addition to the basic logic, four unit logic nodes have been created. These nodes may be described as linked input/output nodes where the initiation of arcs emanating from these nodes is tied to the realization of specific input arcs.

Of special interest here is the modeling versatility afforded the analyst through the user defined nodes. The user may specify the input/output link between any combination of arcs in terms of any combination of successful or unsuccessful input arcs. For example, if the input arcs were ONE, TWO, and THREE, the user could specify that if arc ONE and arc TWO are successful and THREE a failure initiative output arc FOUR, or if arc ONE and THREE are successful initiate arc FIVE, or if ONE is successful and TWO a failure initiate output arc SIX and etc. Any such combination of five input arcs may be linked to five output arcs. The analyst may also incorporate his preference for the initiation of output arcs by using the user defined preference node logic.

The printed output from SOLVNET provides statistical information on the expected duration, cost, and probability of success of the project under study. An index of criticality is provided which indicates how often an arc was on the critical path. A set of three graphs is provided for each terminal node, requested internal nodes, and all terminal nodes combined. The first graph of the set plots completion times versus probability of occurrence. The second plots completion costs versus probability of occurrence, and the third plots frequency of time-cost pairs. The analyst may also request gap statistics for specified node pairs. This request will yield two graphs: time differences versus probability of occurrence and cost differences versus probability of occurrence. Some examples of SOLVNET output are included in Appendix I.

Some special features of SOLVNET include the capability to conduct either a present value or inflation analysis. The user simply inputs the time and percentage factors to utilize this feature. Calendar date output can also be specified in SOLVNET. When this feature is used, network completion dates are printed on the graphs. SOLVNET can also be operated in the interactive mode allowing the analyst to change values without reentering the entire problem. In this mode input format instructions are specified in a near conversational manner.

SOLVNET is a large computer program. The source code requires approximately 150,000 [8] words on the CDC 6500 computer. Conversion of this program to other computers requires the user to rewrite the random number generator. No other major problems were encountered during the conduct of this research in converting SOLVNET for the UNIVAC 1108 computer. The program limits are fixed by the programmer and are outlined in Table 6. Forty error messages are built into the program to assist the user in locating model logic errors and input format errors.

Table 6. SOLVNET Program Limitations

Maximum Number of	Number
Arcs	200
Nodes	150
User Defined Nodes	50
Arcs entering or leaving a node	10
probability output	5
user defined	5
Initial nodes	10
Terminal nodes	30
Gap statistics nodes	5
Iterations	1000
Arcs with universal dist.	100
Arcs with cost-time dist.	100
Arcs with time dependency	50
Arcs with probability dependency	50
Nodes with probability output dependency	25

Among the significant features of SOLVNET is the ability of the user to define the input/output logic for internal nodes. Another feature is the dual dependency computation. SOLVNET requires the user to enter separate dependency relationships if the specified arc or node on which the arc is dependent fails or is successful. SOLVNET is, however, a one-independent-parameter network simulation model. If cost is independent of time, then a separate simulation must be run with cost alone. SOLVNET tacitly assumes that if the proper course of action is determined that minimizes time and related costs, that performance standards will be met. This is certainly not the case in all materiel developmental efforts. It is possible that performance is dependent on cost or time, or independent of both. To analyze performance with SOLVNET or its relationships to cost or time, additional simulations would have to be run. Additional simulations would also be required if critical path analysis is desired on other than the time parameter. SOLVNET does not allow for a weighted combination of its two parameters in this analysis. The analyst may also encounter modeling difficulty. Although dependency relationships are extensive, deterministic transformations are very limited.

The output format can also hinder the model-builder as the available options under SOLVNET are somewhat restrictive. Unless the analyst repeatedly specifies only one iteration he cannot iteratively trace the flow of computations through the network in order to check the known relationships within his model. Without the aid of the programmer (graciously given during the conduct of this thesis) changing the program limits to accommodate a smaller core size or a larger problem is difficult. Still another modeling difficulty is the lack of COMPARE and FILTER logic. This causes problems in modeling key parameters in decision environments. The VERT program has overcome many of these difficulties with few additional limitations.

VERT

VERT, an acronym for Venture Evaluation and Review Technique, is a mathematically oriented simulation networking technique. It is used to assist management in the decision-making process involving risk assessment of an on-going project or any new government or business venture. VERT enables the user to create a fourth dimension risk which is the common measure used to integrate the three principle dimensions of time, cost, and performance. With this technique, time, cost, and performance are the exogenous variables that control the values the exogenous variable 'risk' assumes.

The most significant advantage of the VERT program is the capability of the analyst to model time, cost, and performance values for each activity, jointly or singularly, as a function of other time, cost, and performance parameters in the network or as stochastic variables. To aid in this modeling versatility VERT has twenty-two transformations to express the relationships among key variables. The transformations are listed in Table 7; however, it should be noted that any of the quantities s, y, or z may be values of parameters computed elsewhere in the network.

Table 7. VERT Transformations

Transformation	Restrictions
X*Y*Z = R	
(X*Y)/Z = R	Z NE 0.0
X/(Y*Z) = R	Y*Z NE 0.0
X+Y+Z = R	
1/(X*Y*Z) = R	X*Y*Z NE 0.0
X+Y-Z = R	
X-Y-Z = R	
-X-Y-Z = R	
X*(Y+Z) = R	
X*(Y-Z) = R	
X/(Y+Z) = R	Y+Z NE 0.0
X/(Y-Z) = R	Y-Z NE 0.0
$X*(Y)^{Z} = R$	Y GT 0.0
$X*LOG_{E}(Y*Z) = R$	Y*Z GT 0.0
$X*LOG_{10}(Y*Z) = R$	Y*Z GT 0.0
X*(SIN(Y*Z)) = R	
X*(COS(Y*Z)) = R	
X*(ARCTAN(Y*Z)) = R	
X GE Y ------- Z = R	
X LT Y ------- Y = R	
X GE Y ------- Y = R	
X LT Y ------- Z = R	
X GE Y ------- Z = R	
X LT Y ------- X = R	
X GE Y ------- X = R	
X LT Y ------- Z = R	

The stochastic values of the activity may be expressed in any of fourteen probability distributions embedded in the program. These are the constant, uniform, triangular, normal, lognormal, gamma, weibull, erlang, exponential, Chi square, beta, poisson, Pascall, geometric, binomial, or hypergeometric distributions. If none of these are appropriate, any distribution may be entered in histogram form.

In VERT nodes and arcs are similar in that both have time, cost, and performance attributes. The arcs just discussed have a primary set of time, cost and performance values computed specifically for the activity that arc represents and a cumulative set of values representing the total time expended, cost incurred, and performance generated to process the network to that point. Nodes have only cumulative values.

Like SOLVNET, VERT has two types of nodes. The most common node has split logic which contains composite types of input and output logic. The other VERT node has unit logic whose linked input and output arcs are initiated by the specified logic of the node and the weights assigned by the user. Table 8 describes VERT node logic.

Some cautions are in order when specifying node logic for the VERT program. Arcs emanating from split node logic whose input rule is not satisfied are eliminated from the network, hence using OR input logic and cost pruning options in lieu of PAND may eliminate needed arcs from the network and reduce cumulative cost and performance parameters. The split logic node accumulates time, cost, and performance values for all successful input arcs and transfers this total to each of its initiated output arcs. COMPARE and PREFERRED nodes differ in this respect and will

Table 8. VERT Node Logic Descriptions

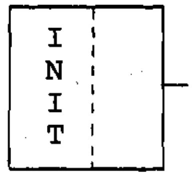
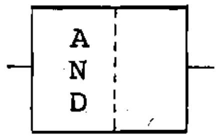
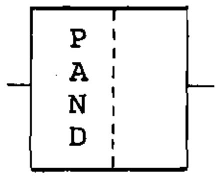
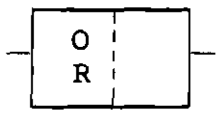
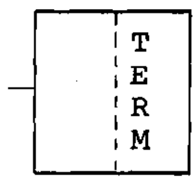
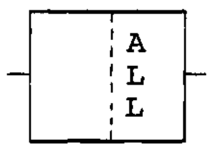
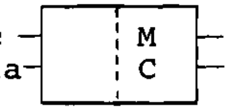
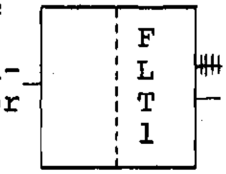
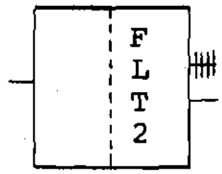
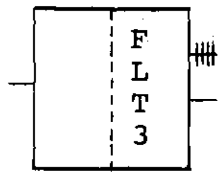
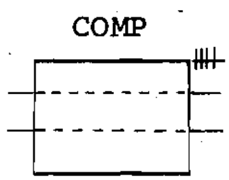
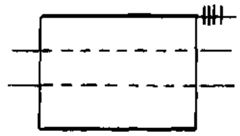
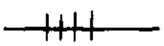
Logic	Description	Symbol	Comments
Input			
INITIAL	INITIAL input logic serves as a start point for the network. Multiple initial nodes may be used.		1
AND	Requires all input arcs to be successfully completed before the network flow can continue through this node.		
PAND	Nearly the same as AND logic, except it requires a minimum of one input arc to be successfully completed before allowing flow to continue through this node.		
OR	Nearly the same as PAND except it only accumulates time, cost, and performance values for the arc having minimum time.		
Output			
TERM	End point for the network.		
ALL	Simultaneously initiates the processing of all the output arcs		

Table 8. Continued

Logic	Description	Symbol	Comments
MC	Initiates the processing of one and only one output arc per simulation iteration via the use of Monte Carlo methods.		2
FLT1	Initiates one or a multiple number of output arcs depending on jointly or singularly satisfying time and/or cost and/or performance (T+/C+/P) boundaries.		3
FLT2	Initiates output arcs based on upper and lower bounds placed on the number of successful input arcs.		
FLT3	Initiates output arcs based on earlier successful or failures of specified arcs.		
	Unit		4
COMPARE	Selects the optimal output arc set for processing via weights entered for time, cost, and performance.		5
PREFERRED	Gives preference to input/output arc combinations as specified by the user.		

 DEFALT ARC

[1]Arcs emanating from nodes with split logic will be eliminated from further consideration for a given iteration

Table 8. Continued

when and only when the input logic cannot be successfully executed. The cumulative time, cost, and performance values assigned to initiated output arcs emanating from a split logic node consists of the sum of the time, cost, and performance values derived for those activities plus the time, cost, and performance values computed for the arc's input node.

[2]MC arcs are initiated randomly via user developed probability weights placed on the output arcs. Multiple sets of probability weights may be entered for the purpose of conditionally randomly initiating the output arc. These sets of probability weights are separated by time or cost or performance (T/C/P) boundaries.

[3]FLT1 boundaries may be different T+/C+/P for each output arc. These boundaries may overlap or be discontinuous for separate output arcs. FLT1 has an optional feature called the subtraction feature. This feature enables temporarily altering this node's T+/C+/P prior to reviewing the output arc's constraints. This alteration consists of temporarily subtracting via absolute arithmetic the T+/C+/P of a designated previously processed node from this node's T+/C+/P.

[4]These nodes have input arcs each mated with a single output arc to enable direct transmission of the network flow from a given input arc to a given output arc. The number of output arcs requested can be specified on a desired or required basis.

[5]If positive weights are entered, the optimal set consists of those output arcs whose corresponding input arcs have the best weighted combination of minimum cumulative time and cost and maximum cumulative performance. Negative weights may be entered. COMPARE and PREFERRED node logic are especially useful for structuring major command or board of director type decisions.

only transfer the accumulated time, cost, and performance values for its linked input arc to individual linked output arcs. Although VERT is relatively uncomplicated, the user can save many hours and trial computer runs by a careful study of VERT node logic. It should be noted that the addition of COMPARE and FILTER logic increases the user's capability to model the real world decision environment.

The VERT program enables the user to specify the weights assigned to performance, cost, and time when determining both the optimal-terminal node and the critical path through the network. Positive weights will select the terminal node with the smallest time and cost and best performance. Positive weights assigned to the critical path analysis would select the path with the longest time, largest cost, and least performance. Negative weights are permitted, but mixed positive and negative values are not permitted. A part of the output selection for VERT permits the user to view the critical path in each iteration or in tabular form via an index of arcs and nodes on the critical-optimum path.

The output options and data generated by VERT are extensive, and are perhaps one of the most important reasons why this program is so useful in network analysis. For each terminal node, the composite terminal node, requested internal nodes, and internal intervals time, cost, and performance results are printed as follows:

1. Relative frequency distribution.
2. Cumulative frequency distribution (ogive).
3. Mean observation.
4. Standard error (standard deviation of the sample).
5. Coefficient of variation.
6. Mode.
7. Beta 2 measure of kurtosis.
8. Pearsonian measure of skewness.

Additionally, time/cost, time/performance, and performance/cost correlations are graphed for all terminal nodes including the composite terminal node. Some other forms of output include:

1. A listing of major variable storage arrays.
2. A listing of all flow-carrying arcs and nodes realized each iteration.
3. A one-line summary listing of the results of each iteration.
4. A listing of the mean, minimum and maximum for the time, path cost, overall cost, and performance for each terminal and requested internal nodes.
5. Time, path cost, and performance correlations.
6. A listing of the optimal terminal node index and an accompanying arcs and nodes critical-optimum path index.

This large quantity of output information makes it possible for the analyst to make an in-depth review of the model and sensitivity of the data structured within it. The addition of the coefficient of variation, beta 2 measure of kurtosis, and Pearson's measure of skewness permits the analyst to compare distributions more precisely. The coefficient of variation is a dimensionless measure of dispersion (standard deviation/mean). Increasing values for the coefficient of variation indicate increasing dispersion. Pearson's measure of skewness ((mean-mode)/ standard deviation) provides a comparison of central tendency. Absolute values for Pearson's statistic that are less than one imply that the distribution is not markedly skewed. The third comparison measure of the distribution provided in VERT is its peakedness or kurtosis. The beta 2 measure of kurtosis (fourth moment about the mean/standard deviation) for the standard normal distribution is three. Examples of VERT output are included in Appendix II.

VERT also has the capability of present value analysis. As in SOLVNET, the analyst inputs a time factor and the interest rate for the analysis. Another significant feature of VERT is the accompanying auxiliary programs. A redimensioning program is available which punches new program cards for the VERT source program. This allows the user to easily contract or expand the capability of VERT to fit a smaller core computer or a larger network application. A second program provides the user with a list of the VERT source program. Error checking within the program is extensive to say the least. One hundred forty-six error messages are embedded in the program and listed in the operating instructions. VERT also includes a cost-pruning option. Arcs in the stream of a network path going into OR logic and COMPARE logic nodes and other arcs may be only partially completed or may never start processing prior to the completion of the simulation. VERT is structured to fully or partially cost those activities partially completed and enables pruning from costing those activities not started.

The VERT program was written for the IBM 360/65 computer in Fortran IV. It is essentially a batch-oriented system with unique punch card options. The user is required to modify read statements and the random number generator prior to conversion to a different computer. During conversion of this program, a logic difference was encountered which did not appear in the original computer. Essentially, it involved the creation of a gamma variate by successively multiplying random numbers and then taking the logarithm of the results. On the smaller-bit UNIVAC 1108 computer repeated multiplication of random numbers less than one resulted in a quantity near zero. Attempting to take the logarithm of this quantity resulted in an error. This difficulty was corrected by successively adding the logarithms of random numbers. The line number modifications of the source program are listed in Appendix III.

Even with the impressive list of transformations and distributions, VERT is not without limitations. The basic program limitations are listed in Table 9. Essentially, there is difficulty in applying some of the transformations, since VERT requires that the arc or node on which transformations are based be successful. No provision is made for a transformation of the data if the the arc or node on which the transformation is based is a failure or is eliminated from the network. There is no provision in VERT for the user to specify the logic for a node as mentioned earlier in SOLVNET; however, FILTER node logic used in combination will yield nearly the same results.

Table 9. VERT Program Limitations

Maximum Number of	Minimum	Maximum
1. Iterations	>0	<100,000
2. Arcs	>0	< 10,000
3. Nodes	>0	< 10,000
4. Internal Histograms Allowed	>0	< 100
5. Terminal Node Histograms	>0	< 1,000
6. Array Storage	>0	<100,000

A Comparison

It is instructive to examine a summary of the differences. Table 10 provides a comparison of many of the

Table 10. SOLVNET/VERT Program Comparison

Item	SOLVNET	VERT
Arc Representation		
Stochastic	Four distributions including a cumulative histogram format.	Eleven distributions including a histogram format.
Deterministic	One transformation.	Twenty-two transformations.
Node Logic	1/1 Bar, Preferred, and User Defined node logic available in addition to basic split node logic.	Compare, Preference, and restrictive Filt logic available in addition to basic split node logic.
Output	Limited to fixed sets of graphs with no options.	Allows the user to select one of four possible extensive output combinations.
Comparison Statistics	Mean, mode, median, and standard deviation.	Mean, mode, standard deviation, coefficient of variation, beta 2 measure of kurtosis, and Pearsonian measure of skewness.
Error Checks	Good.	Extensive.
Sensitivity Analysis	Present value and inflation analysis.	Present value analysis only.
Arc and Node Dependency Relationships	Excellent.	Does not provide for a computation of arc or node on which computation is based is a failure.
Variables	One dependent and one independent variable.	Any combination of three dependent or independent variables.

Table 10. Continued

Item	SOLVNET	VERT
Problem Size Limitations	Fixed by the programmer.	A redimension capability provided by an auxiliary program.
Operation Instructions	Good	Excellent

differences in the two programs. Although the analyst can use either program to aggregate time, cost, and performance profiles, VERT provides a substantially better output. The user is also provided with an increased modeling capability through COMPARE and FILTER node logic, a more accurate representation of data through an extensive list of transformations and probability distributions, and an independent simultaneous accumulation of the three parameters cost, time, and performance with fewer limitations. VERT has been chosen, then, as the vehicle to model risk in the design and conduct of an operational test in the remainder of this thesis.

CHAPTER IV

RISK ASSESSMENT AND TEST DESIGN

Introduction

To this point risk assessment and risk analysis have been discussed and defined and network simulation has been selected as the tool to use in the aggregation of a total risk assessment profile. VERT has been selected as the network simulation model to conduct a risk assessment and risk analysis. The details of how VERT assess risk will now be outlined in terms of its usefulness in an operational test design and evaluation.

Risk Assessment

VERT was developed and designed as a risk assessment tool for a total material development program. A network structured to represent such a program would probably consist of two possible sets of outcomes. Those terminal events indicating success would fall into one set and those indicating failure would fall into another set. Here, the probability of a successful development is the sum of the percent of times each successful event was selected. A far easier method would be to model the network into either total project success or total project failure terminal events. In either case VERT prints out a bar graph of the optimal-terminal node index. It is through the use of this printout that the project risk can be ascertained.

At this point it is useful to recall the definition of risk. Risk is the probability that a project will not be completed within specified time, cost, and performance constraints. VERT permits the selection of this optimum terminal node by the best weighted combination of these factors. Normally, the most successful terminal event would be the one with the shortest time, smallest cost, and best performance. Individual activity time, cost, and performance values are structured within the network; hence, VERT permits one to assess the risk directly from the percentage of times in the iterative simulation that the set of failure terminal nodes were realized. In a network consisting of only a success and a failure node, risk would be read directly from the VERT optimal-terminal node bar chart as the percentage of time that the failure node occurred in the simulation.

The Wight, Zamo example in Chapter III can be easily expanded to a small-scale success/fail test design model by adding arcs from nodes FAILW and FAILZ to FAIL. These arcs would transfer the flow from the internal failure nodes (FAILW and FAILZ) to the total failure node (FAIL). Dependencies on these arcs or split node logic controlling the initiation of these arcs would be structured in such a manner as to be activated only by a dual failure of the

Zamo and the Wight data tests (realization of both node FAILW and FAILZ). For example, if VERT split node logic were used for nodes FAILW and FAILZ, PAND input logic and FILT3 output logic would be appropriate. Since flow cannot be permitted to die within the network an additional terminal node would be required to "bury" the unwanted flows within the network. Unwanted flows would be "buried" by specifying input logic for that node which will never be satisfied. It appears feasible then, to use this methodology to conduct risk analysis in operational testing.

Test Design

The design, conduct, and evaluation of an operational test is a heuristic management effort. Operational tests are designed and conducted to provide a user-oriented evaluation of a defense system throughout the material acquisition cycle. Tests are planned and designed to examine operational issues with emphasis on those issues determined to be critical to the successful employment or use of the system under test. The United States Army Operational Test and Evaluation Agency (OTEA) is the Department of the Army agency charged with the responsibility for planning, designing, conducting, and evaluating operational tests for major Army or DOD (Department of the Defense) systems.

The Operational Test Methodology Guide [40] prepared for OTEA by Operations Research Associates lists nearly all possible sources of operational test planning, design, and evaluation information. No test designer would have sufficient planning background, experience, and knowledge of statistical methodology to bring all these sources to bear on a design or evaluation problem. There is apparently no substitute for first-hand experience; hence, informal interviews with OTEA test designers were an essential part of this research. During the course of these interviews an attempt was made to ascertain the current philosophy of operational test design as practiced by OTEA.

Test design is an art rather than a science and considerable coordination with involved agencies and organizations is required. OTEA test designers are afforded wide latitude in their approach to the problem. Given a design project, the test designer attempts to gain as much background in the system for which he is designing an operational test as possible. He may call upon reports of operational tests of similar systems, contractor reports, developmental test reports, "lessons learned" reports from Army troop units, or other available related publications. He relies heavily on his own background and experience (referred to by one designer as his "institutional memory"). Many test designers use interviews with user troops during the course of their background investigation.

Here the test designer attempts to ascertain what the person who uses the new equipment or similar equipment likes best, likes least, or would like to see incorporated in future designs of new equipment to be used in his military job. He seeks information from these user troops on the factors that affect the operational performance of the equipment they use. If qualified, the test designer may actually operate or use the new system or a similar system for which he has been tasked to design an operational test.

The designer's coordination efforts are continuous and extensive. He must coordinate with OTEA elements who conduct the test to insure that the conditions specified in the test can be realized, elements who evaluate the test to determine if sufficient information will be provided by the test design to resolve critical issues and with technical support elements to determine those technical matters which may be in doubt. The method of employment or doctrine is provided in coordination with the U.S. Army Training and Doctrine Command (TRADOC). The technical support package provided by TRADOC is basic to the test design. Coordination is also required with Army and DOD elements slated to provide the user troops, equipment, facilities, and technical support.

In summary, the test designer prepares an operational test design of a system to resolve the operational issues in coordination with all involved Army and DOD agencies, major commands, and troop units. His design is influenced by the best minds of all relevant DOD agencies and units. It becomes an instrument to evaluate the user-oriented worth of a defense system which is capable of being implemented within existing limitations of units, facilities, and requirements under operational conditions specified by current employment doctrine.

Risk Assessment Applied

One cannot argue with this heuristic process, but at this time no formal measures are employed to assess the risk in the test design. Simulation is suggested by the Operations Research Associates as a tool to use before and after the test is conducted to assess the system. It is proposed then, that network simulation can be used both before and after a test is conducted to assess the risk associated with the design, and in the conduct of the risk analysis, ascertain the criticality of the data to the impact on risk. This will provide the designer or analyst with quantified input to his heuristic plan, giving credence to the confidence he now possesses that the test design is workable.

Operational tests are a sub-event in the total material development effort. Within this sub-event are activities, subtests, or subprograms leading to events or milestones. Associated with these activities are related costs, times, and performance values. These values may not be known precisely, but can be represented by a probability distribution. Procedures useful for eliciting such data have been suggested by Dalkey [9], Northrop [38], and Raiffa [47]. These values may also depend on values determined earlier in the conduct of some other activity or subtest. The outcome of the tests would most likely be a set of successful events and a set of unsuccessful events. These activities, subtests, and subprograms with associated values described stochastically or deterministically leading to events which culminate in a set of successful or unsuccessful events describe a VERT network.

What is required then, for the test designer to add the "fourth dimension" risk to the time, cost, and performance values of individual test activities or subtest is for him to model the network and conduct a network simulation. Following the construction of the model, it is a simple matter for the designer to change values, distributions, and design and then assess the risk of these changes. This is risk analysis. Such analysis takes much of the "what if" questions out of the problem prior to the conduct of the test. Subsequently, it can answer the same "what if" questions in a post-mortum evaluation of the data collected during the test.

Safety regulations during the field conduct of an operational test may prohibit the full implementation of the test design despite the prior coordination. The Chaparrel Test Design Plan [41] and subsequent test report [42] is an example of this. It is suggested here that network simulation can assess the risk associated with field limitations imposed on operational tests.

Data Analysis

The simulation also makes it possible to assess the criticality of data. If such alterations in data have a significant impact on the risk associated with the test, it may be necessary to spend additional test dollars in the collection of this data or provide additional instrumentation or observation of this activity or subtest to insure the accuracy of the information. Similarly, it may be discovered that some data has no relevance to the outcome of the test. This activity may be reduced or eliminated and save costly sampling. Other prior data analysis may indicate the need for additional activities or subtests. Simulation may also indicate that project costs, performance and time allocations are insufficient given the individual activity values. Adjustments may be required to these individual activity parameters which would substantially increase the risk. With this information the decision-maker may choose instead to alter total project costs, performance, or time allocations.

In summary, it appears that the heuristic effort of the test designer can be modeled into a network. Using actual test data or subjective projections for individual activity or subtest information, the designer can aggregate these into values for the total project and assess the risk for that project and the influence of data on that risk by using network simulation. This procedure will be illustrated using VERT in Chapter V.

CHAPTER V

AN APPLICATION, THE FALCON

The Falcon

The Commander of OTEA has been tasked to conduct the second Operational Test (OTII) of the Falcon Air Defense System. The Falcon is a highly mobile system capable of providing the Army Corps Commander with strategic all-weather air defense capability for Corps forces. The basic components are mounted in separate track vehicles. System components include a radar acquisition and identification van, tracking and fire control van, communication van, and missile carriers. The missile warhead is nuclear capable and minimum safety range for friendly troops has been set at two kilometers. System features include computer directed identification, tracking, and firing with manual overrides based on predetermined air defense warning status.

The Commander of OTEA has directed that further live firings during OTII are unnecessary since sufficient missile reliability under operational conditions was demonstrated and evaluated under Operational Test I (OTI). TRADOC has asked that three basic doctrines be tested to determine the most effective employment posture. Simply stated, they involve the method of employing the radar of the system. The first proposed doctrine specifies that the radar be employed on site with the missile carriers and associated equipment. The second doctrine dictates employment of the detection radar van forward of the firing site and the third proposal dictates the placement of the radar on line with the firing units but independent of the launch site. Figure 4 provides schematics of TRADOC's employment doctrine proposals.

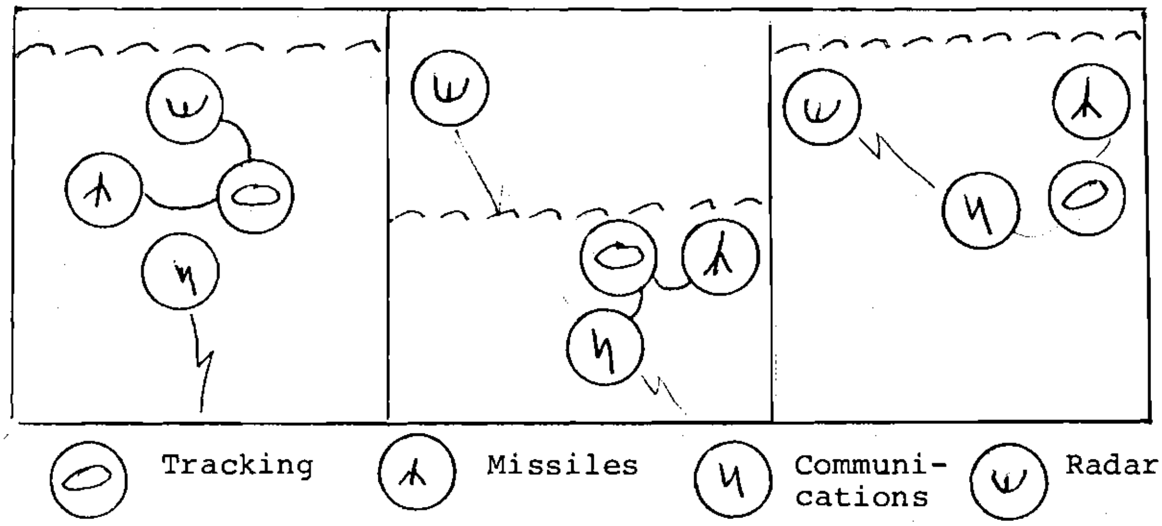


Figure 4. TRADOC Proposed Employment Doctrines

Since the first operational test was conducted (OTI), an improved version of the detection radar has been developed and has demonstrated to be more reliable in contractor reliability and maintenance tests. Its ability to detect and identify under operational conditions has been designated a critical issue for OTII. Another significant improvement in the Falcon Air Defense system has been the development of a laser tracking and firing system versus the existing manual radar assisted system employed in OTI. It has been shown to be a significant improvement under conditions of poor visibility. Laser performance has also been designated a critical issue for OTII. Since fuel is in short supply, tactical and strategic aircraft sorties are limited.

In coordination with the Army Deputy Chief of Staff for Operations (DCSOPS), the U.S. Army Forces Command (FORSCOM) and the U.S. Army Training and Doctrine Command (TRADOC), and OTEA elements, the following test issues have been approved:

1. How will the improved radar affect the Falcon's detection capability?
2. How will ECM degrade the improved radar's acquisition range?
3. What effect will the reliability of the individual components have on the operational availability of the system?
4. Does laser tracking and firing significantly improve firing ranges under reduced visibility?
5. Will altitude affect the tracking and firing of the Falcon system?
6. Is the laser tracking and firing component significantly better than the existing manual radar assisted tracking component?
7. What effect does the status of weapons control have on the employment doctrines proposed by TRADOC?

User troops will be provided by FORSCOM and trained on the Falcon Air Defense System by TRADOC's U.S. Army Air Defense Center and School, Fort Bliss, Texas. The test variables as identified by the operational test issues are ECM, reliability, altitude, weather, and weapon control status. In view of these operational issues and the test variables, the analyst has designed a test to be conducted in four phases.

Phase I is identified as the detection phase. In this phase competing systems are the basic radar system and the improved radar system. The factors to be tested here are the effect of ECM and radar reliability on the detection capability of the Falcon. Detection ranges will be computed for the basic and improved radars in an ECM environment and without the affect of ECM. At the completion of phase I the system detecting hostile aircraft at the greatest range under the conditions (ECM on or ECM off) which have the greatest affect on the degradation of the range of the Falcon will be chosen for use in phase II (i.e., the improved radar under ECM environment).

Phase II is designated as the tracking and firing phase. The factors of visibility, reliability, and altitude are to be varied or tested during this phase. Competing laser and manual radar assisted tracking will be compared to select the system combination firing at the greatest range under the combination of conditions which has the greatest degradation affect on the firing range.

Following the completion of phases I and II that combination of detection and tracking components demonstrating the best performance in terms of greatest detection and firing ranges under those conditions which provided the greatest negative effect on that range will be assembled to provide the system under which the TRADOC employment doctrines will be tested in phases III and IV.

During phase III, the three proposed TRADOC employment procedures will be tested on platoon size system units. The factors contributing to performance here are weapon control status and availability. Performance under each of the weapon control states will be averaged and the two employment doctrines demonstrating the greatest detection, tracking, and firing ranges will be selected for the battalion size doctrine test.

The last employment doctrine test is designed to provide a full-scale operational environment and select the best employment doctrine under the conditions prescribed earlier with the best system developed during phases I and II. At each point throughout the test cycle a check will be made to insure that detection ranges are greater than 5 kilometers and firing ranges are greater than 2 kilometers.

The Model

In order to conduct a risk analysis of the phased procedure just described, the designer must now build a network model. At this point the model cannot be built independent of the program which is chosen to analyze the model. VERT has been selected as the network simulation tool to be used to conduct a risk assessment of Falcon, hence VERT transformations of data and VERT node logic are used to build the Falcon test model.

Figures 5, 6, 7, and 8 provide a schematic of the Falcon operational test and Tables 11 and 12 provide a description of the model's arcs and nodes.

VERT logic is particularly suited to the decisions proposed by the test designer throughout the conduct of the phased operational test for the Falcon. In phase I (Figure 5) the initial organization, personnel, and equipment costs are represented by ORGT. ORGT also carries the time projection for the organization of the test directorate in terms of weeks. The two competing systems then split along identical paths. To illustrate the logic, the upper path which represents the improved radar test will be followed. Basic range, time, and cost data is computed by IMPR and checked by IMPSC's FILT1 logic to insure that the detection range is in excess of 5 kilometers. Degradations to the basic range are carried by arcs IECO and IECF representing the effect of EMC on the Falcon system.

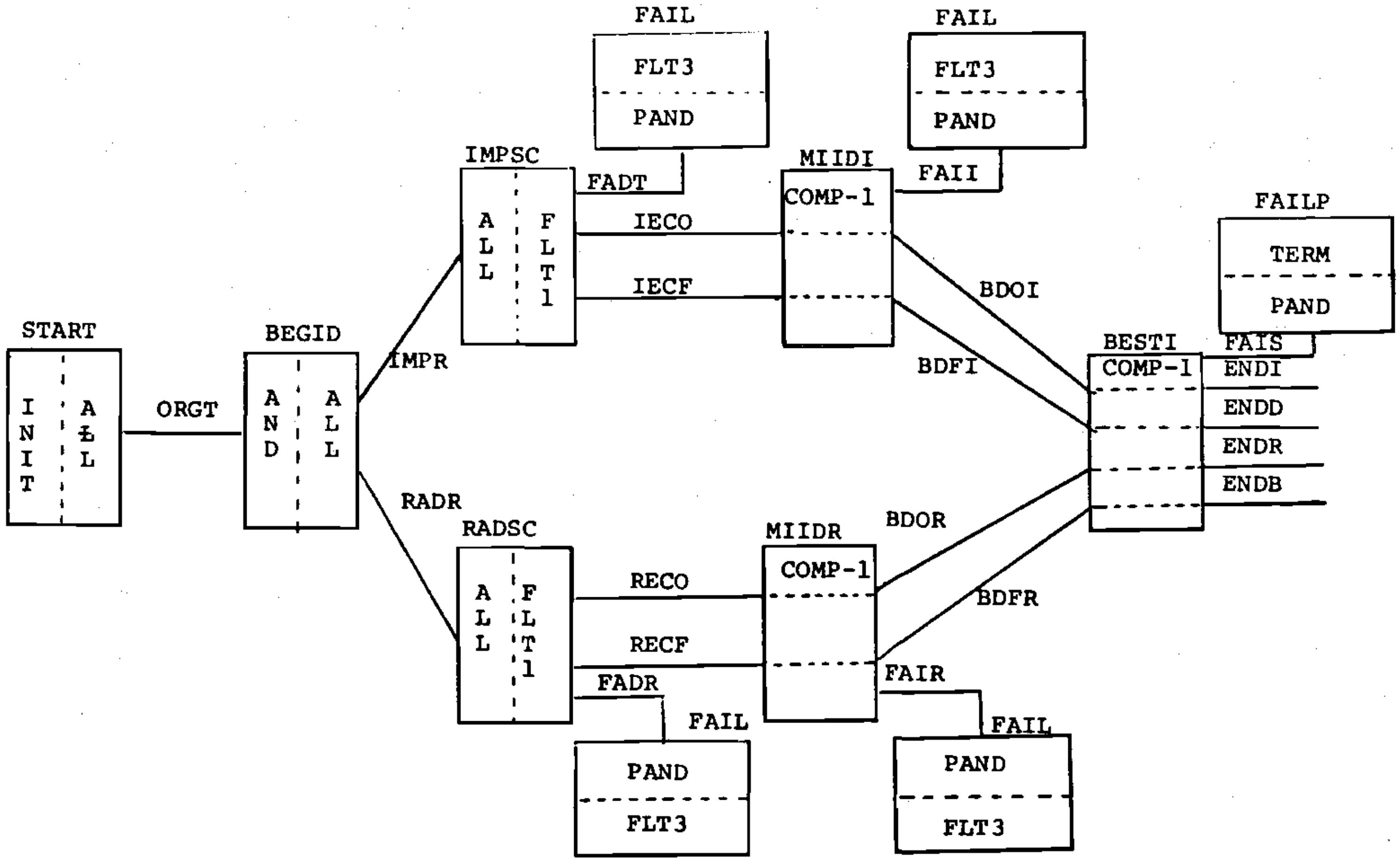


Figure 5
Phase I Falcon Operational Test

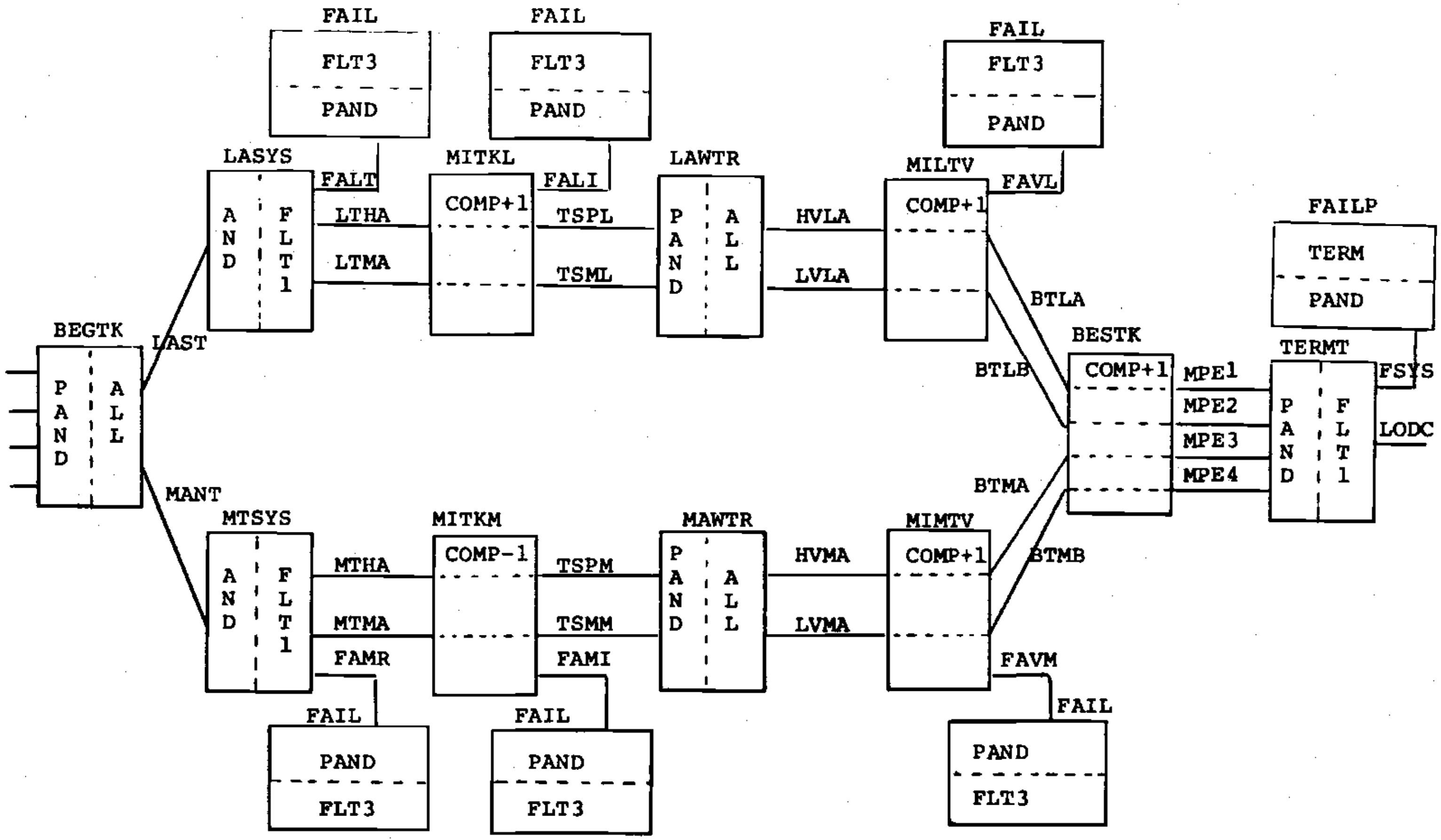


Figure 6
Phase II Falcon Operational Test

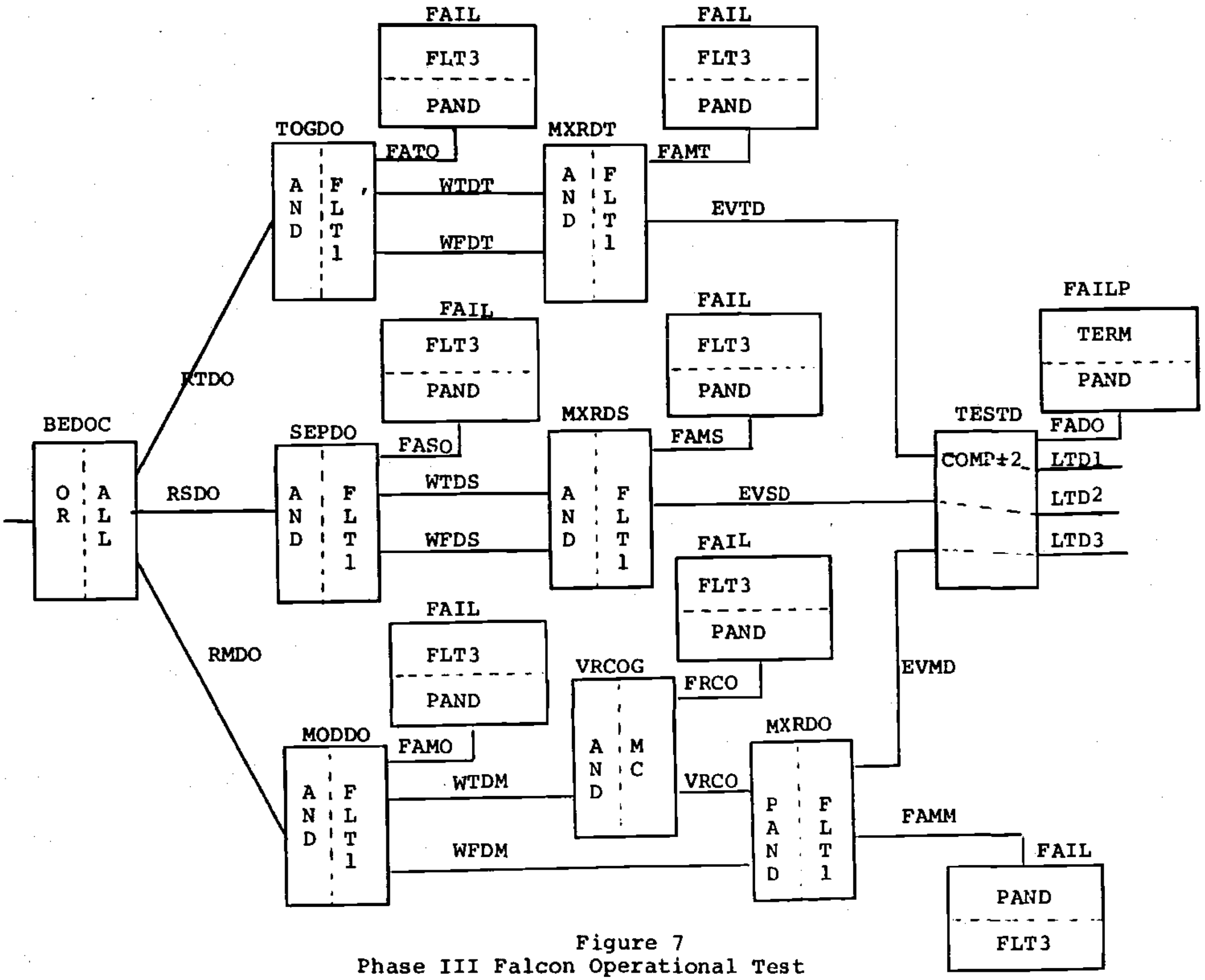


Figure 7
Phase III Falcon Operational Test

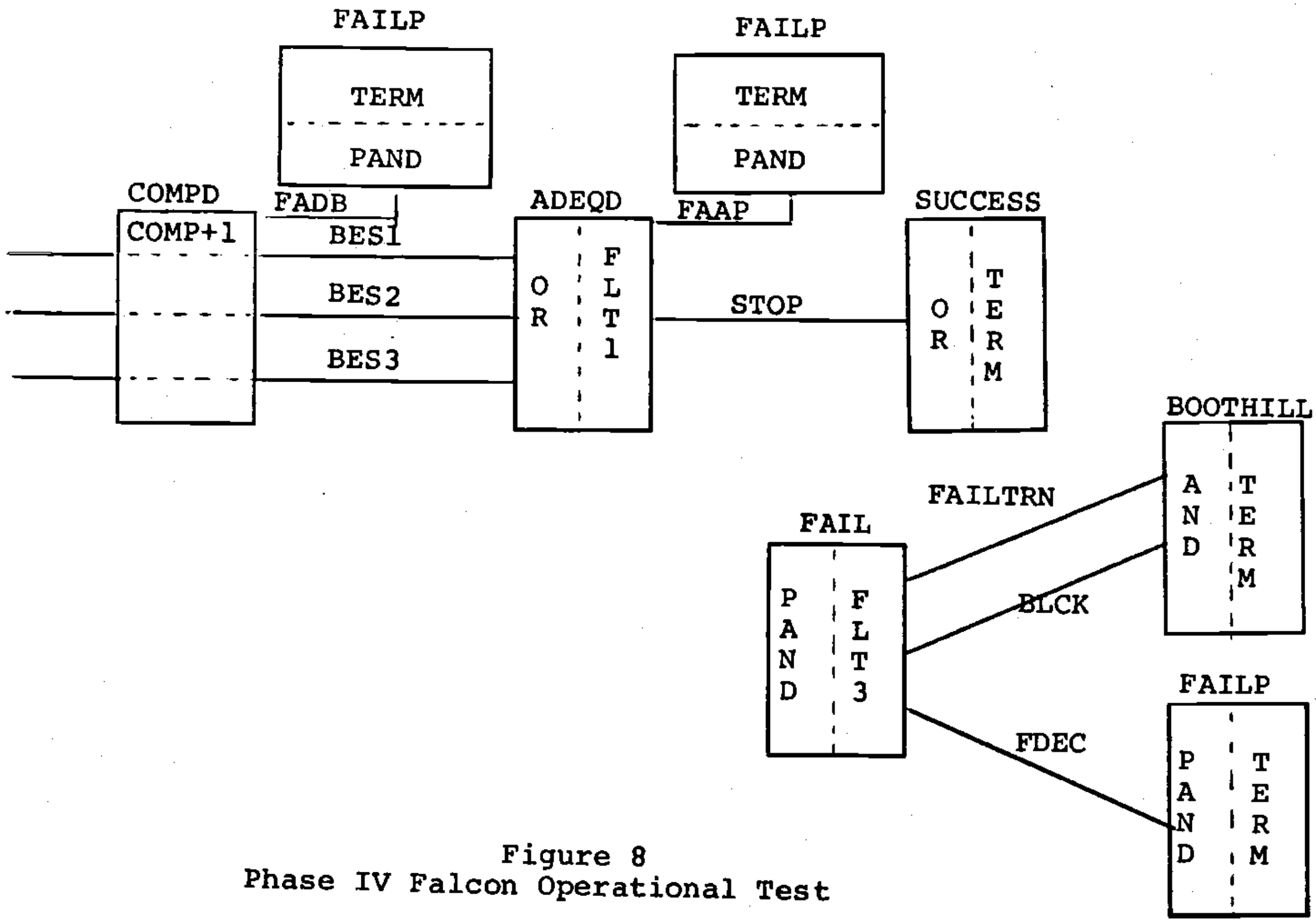


Figure 8
Phase IV Falcon Operational Test

Table 11. Falcon Arc Descriptions

Arc	Description
ORGT	Organize test directorate.
IMPR	Improved radar detection test.
RADR	Basic radar detection test.
IECO	Improved radar in ECM environment test.
IECF	Improved radar with no ECM effect.
FADT	Improved radar fails to detect greater than 5 kilometers.
RECO	Basic radar in ECM environment test.
RECF	Basic radar with no ECM effect test.
FADR	Basic radar fails to detect hostile aircraft at range greater than 5 kilometers.
FAII	Default arc for comparison node, indicates that a reliability failure occurred in the ECM test.
BDOI	Transportation arc indicating that ECM on proved the worst range degradation.
BDFI	Transportation arc indicating that ECM off proved to provide the worst range degradation.
FAIR	Default arc for comparison node, indicates that a dual reliability failure occurred in the EMC test for the basic radar.
BDOR	Transportation arc indicating that ECM on proved to provide the worst range degradation for the basic radar.
BDFR	Transportation arc indicating that ECM off proved to provide the worst range degradation for the basic radar.
FAIS	Default arc for detection phase failure node, indicates a failure of all detection tests.
ENDI	Improved radar operating in an ECM environment selected as the system at the completion of phase I.

Table 11. Continued

Arc	Description
ENDD	Improved radar operating with no ECM effect selected as the system combination at the completion of phase I.
ENDR	Basic radar operating in an ECM environment selected as the system combination at the completion of phase I.
ENDB	Basic radar operating with no ECM effect selected as the system combination at the completion of phase I.
LAST	Laser track/fire test, basic data.
MANT	Manual radar assisted track/fire test, basic data.
FALT	Laser failed to fire at hostile aircraft at ranges in excess of 3 kilometers from the firing point.
LTHA	High altitude flights laser track/fire test.
LTMA	Medium altitude flights laser track/fire test.
FALI	Default arc for comparison node, indicates that a dual reliability failure occurred in the laser altitude test.
MTHA	Manual radar assisted high altitude track/fire test.
MTMA	Manual radar assisted medium altitude track/fire test.
FAMR	Manual radar assisted failed to fire at hostile aircraft at ranges in excess of 3 kilometers from the firing point.
TSPL	Transportation arc indicating that the high altitude flights provided the worst range degradation for laser tracking.
TSML	Transportation arc indicating that the medium altitude flights provided the worst range degradation for laser tracking.

Table 11. Continued

Arc	Description
FAMI	Default arc for comparison node, indicates that a dual reliability failure occurred in the manual tracking tests.
TSPM	Transportation arc indicating that the high altitude flights provided the worst range degradation for manual tracking.
TSMM	Transportation arc indicating that the medium altitude flights provided the worst range degradation for manual tracking.
HVLA	High visibility laser tracking test.
LVLA	Low visibility laser tracking test.
HVMA	High visibility manual tracking test.
LVMA	Low visibility manual tracking test.
FAVL	Default arc for comparison node, indicates a dual reliability failure for the visibility laser tracking tests.
BTLA	Transportation arc indicating that high visibility provided the worst range degradation for laser tracking.
BTLB	Transportation arc indicating that low visibility provided the worst range degradation for laser tracking.
FAVM	Default arc for comparison node, indicates a dual reliability failure for the visibility manual tracking tests.
BTMA	Transportation arc indicating that high visibility provided the worst range degradation for manual tracking.
BTMB	Transportation arc indicating that low visibility provided the worst range degradation for manual tracking.

Table 11. Continued

Arc	Description
FATK	Default arc for comparison node, indicates a failure of all tracking tests.
MPE1	Laser tracking, high visibility combination selected at the completion of phase II.
MPE2	Laser tracking, low visibility combination selected at the completion of phase II.
MPE3	Manual tracking, high visibility combination selected at the completion of phase II.
MPE4	Manual tracking, low visibility combination selected at the completion of phase II.
FSYS	System selected at the completion of phase II failed to track and fire at hostile aircraft at ranges in excess of 2 kilometers from the firing site.
LODC	Organize doctrine test.
RTDO	Radar on site with firing units employment doctrine test.
RSDO	Radar separate from firing units doctrine test.
RMDO	Radar separate but on line with firing units doctrine test.
FATO	On site doctrine fails to engage aircraft greater than 2 kilometers from the firing site.
WTDT	Weapons tight control test for together doctrine.
WFDT	Weapons free control test for on site doctrine.
FASO	Radar separate doctrine units failed to engage hostile aircraft at ranges greater than 2 kilometers from the firing site.
WTDS	Weapons tight control test for separate doctrine.
WFDS	Weapons free control test for separate doctrine.

Table 11. Continued

Arc	Description
FAMO	On line but separate doctrine units failed to engage hostile aircraft at ranges greater than 2 kilometers from the firing site.
WTDM	Weapons tight control test for on line separate doctrine.
WFDM	Weapons free control test for on line separate doctrine.
VRCO	Hostile aircraft visually identified test successful.
FRCO	Hostile aircraft failed to be visually identified.
FAMT	On site doctrine again fails 2 kilometer minimum.
EVTD	Transportation arc for on site doctrine.
FAMS	Separate doctrine fails the 2 kilometer minimum.
EVSD	Transportation arc for separate doctrine.
FAMM	On line but separate doctrine fails the 2 kilometer minimum.
EVMD	Transportation arc for on line but separate doctrine.
FADO	Default arc for comparison node indicating that all doctrine tests were failures.
LTD1	On site doctrine selected as the best.
LTD2	Separate doctrine selected as the best.
LTD3	On line but separate doctrine selected as one of best two for input into battalion doctrine test.
BES1	On site doctrine selected as the best after battalion size test.
BES2	Separate doctrine selected as the best after battalion size test.

Table 11. Continued

Arc	Description
BES3	On line but separate doctrine selected as the best after the battalion size test.
FADB	Default arc for comparison node, indicates a failure of all battalion doctrine tests.
FAAP	Final check to insure that selected system has engaged hostile aircraft in excess of 2 kilometers from the firing site.
STOP	Transportation arc to node SUCCESS.
FAILTRN	Default arc for node FAIL.
BLCK	Transportation arc for node FAIL, this coupled with FAILTRN buries unwanted flows within the network.
FDEC	Transportation arc for node FAIL, this arc is realized when there is a dual failure within the network.

Table 12. Falcon Node Descriptions

Node	Description
START	Start point for the network.
BEGID	Directorate organized.
IMPSC	Basic test data point improved radar.
RADSC	Basic test data point basic radar.
MIIDI	Selects the minimum distance for the ECM test, improved radar.
MIIDR	Selects the minimum distance for the ECM test, basic radar.
BESTI	Selects the system detecting at the greatest range.
BEGTK	End of phase I, begin phase II.
LASYS	Basic data test point laser tracking.
MTSYS	Basic data test point manual tracking.
MIKKL	Selects the minimum distance for the altitude test, laser tracking.
MITKM	Selects the minimum distance for the altitude test, manual tracking.
LAWTR	Start point for visibility test, laser tracking.
MAWTR	Start point for visibility test, manual tracking.
MILTV	Selects the minimum distance for the visibility test, laser tracking.
MIMTV	Selects the minimum distance for the visibility test, manual tracking.
BESTK	Selects the maximum distance for the tracking phase of the test.
TERMT	End of the tracking phase of the test.
BEDOC	Start point for the doctrine phase of the test.

Table 12. Continued

Node	Description
TOGDO	Basic data point for the on site doctrine test.
SEPDO	Basic data point for the separate doctrine test.
MODDO	Basic data point for the on line but separate doctrine test.
VRCOG	Begin visual recognition test.
MXRDT	Complete on site doctrine test, check minimum performance.
MXRDS	Complete separate doctrine test, check minimum performance.
MXRDO	Complete on line but separate doctrine test, check minimum performance.
TESTD	Select best two doctrines for input to phase IV.
COMPD	Select best doctrine.
ADEQD	Check to see that minimum standards are met.
FAIL	Collection point for failure flows.
FAILP	Failure of the operational test.
SUCCESS	Success of the operational test.
BOOTHILL	Buries unwanted failure flows.

The cost of using ECM is also included on arc IECO. These degradations are compared using VERT COMPARE node logic. The selection here is based on a negative performance (i.e., the minimum range of the two competing arcs will be selected). Each of these arcs has a probability of less than one of being completed once initiated. This value indicates the reliability of the radar system component. In the event both fail, arc FAII will be initiated. The two competing systems then merge at node BESTI which uses weighted COMPARE logic to select the winning arc. A positive value for performance is used here since maximum range is desired. Realization of one of the four arcs emanating from node BESTI will select the system and conditions for phase II of the Falcon operational test.

In phase II, competing laser and manual radar assisted tracking systems are represented by separate paths (Figure 6). Initial values of time, cost, and range are computed by LAST and checked by LASY's FILT1 logic to insure that the firing range is in excess of 3 kilometers from the firing site. The degradation to these basic range values, the reliability of laser altitude tracking, and increased costs of low altitude flying are carried on arcs LTHA and LTMA. These values are compared by MITKL and the altitude factor yielding the minimum range is selected. Similarly the range degradation, reliability of laser tracking under varied visibility conditions, and the higher costs associated with restricted visibility flying are carried on arcs HVLA and LVLA. Again the minimum range is selected by MILTV. Arcs BTLA and BTLB carry additional system availability into node BESTK where the system factor combination producing the best firing range is selected. TERMT's FILT1 logic checks this selected system to insure that it has met minimum performance standards (firing range greater than 2 kilometers at the completion of the tracking and firing phase of the operational test).

Since performance values are not to be carried over into the doctrine phase of the test, they are set to zero prior to the start of phase III of the operational test. Here the three doctrines proposed by TRADOC follow three separate paths (Figure 7). Following the pattern set in earlier phases, basic cost, time, and performance data is computed by the initial arcs (RTDO, RSDO, and RMDO) and checked to insure that minimum standards are met. Alterations to these basic inputs are carried on the weapons control arcs emanating from nodes TOGDO, SEPDO, and MODDO. Nodes MXRDT, MXRDS, and MXRDO again check to insure that the firing range is in excess of 2 kilometers. Arcs EVTD, EVSD, and EVMD carry system availability data and accumulated range for comparison by TESTD. TESTD selects the two doctrines engaging aircraft at maximum ranges for input into phase IV.

The effect of weapons control status is carried into phase IV (Figure 8) by the winning arcs emanating from TESTD. Hence, only the degradation of range encountered in a large scale test need be represented by arcs LTD1, LTD2, and LTD3. Node COMPD selects the winning employment doctrine and node ADEQD checks the performance of this doctrine for the minimum standard that has been referred to.

Node FAIL accumulates failure flows and through FILT3 logic will transfer that flow to node FAILP only if arc STOP is unsuccessful. Similar logic would prevent the simultaneous initiation of arcs FAILTRN and BLCK, hence, BOOTHILL's and logic will never be satisfied.

The Data

The operational test designer has many sources for data to provide necessary detail for the model. Much of the performance, reliability, and cost data has been generated in contractor developmental tests or in earlier operational tests. In lieu of these, the procedures mentioned earlier as outlined by Dalkey [9], Northrop [38], and Raiffa [47] may be useful for assigning numerical relationships and probability distributions to values for time, cost, and performance. Once initial values are assigned, analysis becomes possible through systematically changing these values.

In most cases the analyst will be reasonably sure of the range of values over which activities within the network model will vary. However, he may not know the shape of the distributions within that operational range. In the absence of sufficient information, the analyst would most likely assume that his probability distributions were normal. They may, however, be completely random over the interval (uniform), skewed to the left or right (gamma), or some combination of these. The analyst is also concerned about the effect of the values assigned to determine the critical path and the effect of present value discounting on project costs.

To illustrate these points, VERT was used to analyze the Falcon operational test model. With the exception of cost/time dependency relationships, initial data values were given normal distributions. Since performance is critical in the Falcon model, a plus one value on performance was assigned for critical path and optimum-terminal node analysis, and no present value discounting was used. A subsequent run with normal data used a minus one value for performance in critical path and optimum-terminal node analysis. Still another run with normal data was used to test the effect of present value discounting on Falcon cost values. In subsequent runs strictly uniform distributions, gamma, and exponential distributions with different means were used.

A summary of data inputs is included in Appendix IV. Table 13 presents a comparison of critical path variations between specified runs, Table 14 summarizes the comparison

Table 13. Falcon Critical Path Comparisons

Node	1	1a	2	3	4
START	1.000	1.000	1.000	1.000	1.000
BEGID	1.000	1.000	1.000	1.000	1.000
IMPSC	.558	.600	.580	.560	.510
RADSC	.442	.400	.420	.440	.490
MIIDI	.554	.398	.546	.560	.366
MIIDR	.432	.398	.392	.440	.352
BESTI	.986	.986	.938	.992	.718
BEGTK	.986	.986	.938	.992	.718
LASYS	.302	.340	.468	.358	.268
MTSYS	.684	.646	.470	.634	.450
MITKL	.300	.338	.442	.356	.200
MITKM	.678	.640	.452	.630	.398
LAWTR	.300	.338	.440	.356	.200
MAWTR	.678	.638	.452	.630	.398
MILTV	.300	.338	.440	.356	.200
MIMTV	.678	.638	.452	.630	.398
BESTK	.978	.976	.890	.986	.598
TERMT	.968	.966	.884	.978	.598
BEDOC	.958	.948	.846	.954	.522
TOGDO	.124	.376	.198	.254	.144
SEPDO	.168	.402	.232	.254	.090
MODDO	.666	.170	.416	.446	.288
VRCOG	.004	.000	.000	.006	.000
MXRDT	.124	.376	.232	.238	.122
MXRDS	.168	.402	.232	.254	.088
MXRDO	.662	.170	.410	.396	.234
TESTD	.954	.948	.832	.880	.444
COMPD	.954	.948	.832	.880	.444
ADEQD	.950	.946	.828	.878	.444
FAIL	.050	.054	.172	.128	.562
SUCCESS	.950	.946	.828	.878	.438
FAILP	.050	.054	.172	.128	.552
Arc					
ORGT	1.000	1.000	1.000	1.000	1.000
IMPR	.588	.600	.580	.560	.510
RADR	.442	.400	.420	.440	.490
FADT	.004	.002	.034	.000	.144
IECO	.502	.508	.484	.468	.312
IECF	.052	.090	.062	.092	.054
FADR	.010	.002	.028	.008	.138
RECO	.364	.334	.338	.362	.320
RECF	.068	.064	.054	.070	.032
FAII		.006			
BDOI	.502	.502	.484	.468	.312

Table 13. Continued

Arc	1	1a	2	3	4
DBFI	.052	.090	.062	.092	.054
FAIR		.004			
BDOR	.364	.330	.338	.362	.320
BDFR	.068	.064	.054	.070	.032
ENDI	.502	.502	.484	.468	.312
ENDD	.052	.090	.062	.092	.054
ENDR	.364	.330	.338	.362	.320
ENDB	.068	.064	.054	.070	.032
LAST	.302	.340	.468	.358	.268
MANT	.684	.646	.470	.634	.450
FALT	.002	.002	.026	.002	.068
LTHA	.276	.320	.366	.340	.182
LTMA	.024	.028	.076	.016	.018
FAMR	.006	.006	.018	.004	.052
MTHA	.664	.608	.418	.584	.372
MTMA	.034	.032	.034	.046	.026
TSPL	.276	.310	.366	.340	.182
TSML	.024	.028	.074	.016	.018
TSPM	.644	.606	.418	.584	.372
TSMM	.034	.032	.034	.046	.026
HVLA	.146	.156	.180	.176	.092
LVLA	.154	.182	.260	.180	.108
HVMA	.104	.080	.086	.092	.068
LVMA	.574	.558	.366	.538	.330
BTLA	.146	.156	.180	.176	.092
BTLB	.154	.183	.260	.180	.108
BTMA	.104	.080	.084	.092	.068
BTMB	.574	.558	.366	.538	.330
MPE1	.146	.156	.180	.176	.092
MPE2	.154	.174	.260	.178	.108
MPE3	.102	.080	.080	.090	.068
MPE4	.566	.556	.364	.534	.330
FATK	.010	.010	.006	.008	
FSYS	.010	.018	.038	.024	.076
LODC	.958	.948	.846	.954	.522
RTDO	.124	.376	.198	.254	.144
RSDO	.168	.402	.232	.254	.090
RMDO	.666	.170	.416	.446	.288
FATO			.006	.016	.022
WFDT	.124		.192	.238	.122
WTDT		.376			
WFDS	.168		.232	.254	.088
WTDS		.402			
FAMO					.054
WTDM	.004		.006	.044	
WFDM	.662	.170	.410	.396	.234

Table 13. Continued

Arc	1	1a	2	3	4
FAMT			.002	.004	
FRCO	.004			.006	
EVTD	.124	.376	.190	.234	.122
EVSD	.168	.402	.232	.250	.088
EVMD	.662	.170	.410	.396	.234
LTD1	.116	.100	.190	.224	.124
LTD2	.150	.136	.220	.240	.082
LTD3	.688	.712	.422	.416	.238
FADB	.004	.002	.004	.002	
BES1	.116	.100	.190	.224	.124
BES2	.150	.134	.216	.240	.082
BES3	.684	.712	.422	.411	.238
FAAP				.006	.006
STOP	.950	.946	.828	.872	.438
FDEC	.050	.054	.172	.128	.562

Note: The values computed in columns 1, 2, 3, and 4 were obtained by assigning a +1.0 to performance in the weighted critical-optimum path analysis, hence the selection criteria is the worst performance value. Column 1a was obtained using the opposite value (-1).

Table 14. Falcon Distribution Statistics

Composite	Parameter	Statistic	1	2	3	4
BEGTK	Time	1	2.08	2.12	2.14	2.03
		2	2.10	2.10	2.36	*
		3	.31	.38	.34	.36
		4	.06	.06	.62	*
		5	.15	.18	.16	.18
		6	2.31	2.52	2.71	2.65
	Cost	1	43.80	43.00	74.07	65.91
		2	43.51	43.96	76.06	62.13
		3	3.98	6.77	10.66	12.50
		4	.07	.14	.19	.30
		5	.09	.16	.14	.19
		6	3.17	2.69	2.74	2.85
	Range	1	19.17	17.84	18.47	10.65
		2	18.71	18.63	18.80	5.46
		3	6.12	7.96	6.50	7.87
		4	.08	.10	.05	.66
		5	.32	.45	.35	.74
		6	2.61	2.42	2.61	2.91
TERMT	Time	1	3.77	4.28	4.16	4.00
		2	3.83	4.59	4.84	4.96
		3	.75	.70	.97	1.00
		4	.07	.44	.71	.96
		5	.20	.16	.23	.25
		6	2.40	2.51	1.97	2.00
	Cost	1	95.87	106.46	167.95	154.36
		2	89.77	111.33	169.86	*
		3	15.03	16.33	37.33	35.54
		4	.41	.30	.05	*
		5	.16	.15	.22	.23
		6	2.68	2.93	2.35	2.45
	Range	1	14.64	12.81	13.90	8.32
		2	13.84	13.18	14.79	*
		3	6.24	7.57	6.64	7.27
		4	.13	.05	.13	*
		5	.43	.59	.48	.87
		6	2.44	2.25	2.59	2.92
SUCCESS	Time	1	8.35	10.20	8.76	8.54
		2	8.55	9.87	8.82	*
		3	.92	1.16	1.09	1.13
		4	.23	.29	.06	*
		5	.11	.11	.12	.13
		6	2.46	2.58	2.42	2.16
	Cost	1	171.30	200.71	320.00	308.87
		2	163.53	201.32	304.44	318.22
		3	15.72	19.78	38.66	36.42
		4	.49	.04	.40	.26

Table 14. Continued

Composite	Parameter	Statistic	1	2	3	4
		5	.09	.10	.12	.12
		6	2.56	2.85	2.31	2.49
	Range	1	9.62	11.70	11.66	8.15
		2	9.89	*	18.04	6.80
		3	1.87	3.85	5.02	4.30
		4	.15	*	1.27	.31
		5	.19	.33	.43	.53
		6	2.79	2.41	1.81	2.83
COMPOSITE	Time	1	8.11	9.23	8.38	6.03
		2	8.50	10.10	9.00	4.77
		3	1.38	2.49	1.62	2.68
		4	.28	.35	.38	.47
		5	.17	.27	.19	.44
		6	7.85	3.77	4.49	1.67
	Cost	1	166.75	182.07	308.43	214.00
		2	168.49	202.51	*	*
		3	26.13	47.58	55.23	103.36
		4	.07	.43	*	*
		5	.16	.26	.18	.48
		6	10.58	4.36	5.41	1.62
	Range	1	9.25	9.87	10.70	5.20
		2	8.84	*	*	5.99
		3	2.55	5.46	5.78	4.51
		4	.16	*	*	.17
		5	.28	.55	.54	.87
		6	6.15	2.58	2.37	3.66

Notes: * indicates a multimodal distribution; 1 = Mean; 2 = Mode; 3 = Standard Error; 4 = Pearsonian Measure of Skewness; 5 = Coefficient of Variation; 6 = Beta 2 Measure of Kurtosis.

statistics and Table 15 summarizes the optimum-terminal node selection. Since risk is of concern here, and a network has been constructed which aggregates all failures into a single node, the risk in a set of inputs is represented by the percentage of time that node FAILP is realized in Table 15.

Table 15. Falcon Optimum-Terminal Node Selections

	1	2	3	4
SUCCESS	.950	.828	.872	.430
FAILP	.050	.172	.128	.562

Although the data is listed in VERT input format in Appendix IV and a capsule summary given earlier, a recap will aid in the reader's analysis of the results tabulated in Tables 13, 14, and 15. Columns 1 and 1a represent data which is essentially normal. Time is independent of performance but some costs in the model are tied to the amount of time necessary to conduct the test and the number of aircraft sorties required in the conduct of the test. The difference in these two columns lies in the value chosen to analyze the critical-optimum path and the optimum-terminal node. In VERT runs listed in columns 1, 2, 3, and 4 a plus one value for performance was given to conduct these analyses and in column 1a a minus one value was given to produce comparison data. Column 2 Falcon results are from data which uses the same end points and cost/time dependencies with uniform distributions. The results of the VERT analysis of the Falcon air defense operational test given in columns 3 and 4 combine independent gamma, exponential, and normal performance distributions. Time distributions are combined from normal and triangular distributions and cost distributions are aggregated from exponential and normal distributions. Some costs in these runs are still related to time values computed during the analysis. The difference in these two columns is the alteration of the mean for many performance distributions and the addition of exponential costs for some values in column 4. Throughout the analysis the integrity of the end points was maintained.

Table 13 indicates that the critical path through the network is sensitive to the value assigned to the analysis in phase III of the test. The critical path encountered by selecting arcs which provide the least performance (positive value) are those which represent the Falcon on line but separate employment doctrine. The other two paths share evenly the remaining time percentage in the critical path analysis. When the best performance is specified in the analysis (negative values) the compliment of this is true. A review of the test design plan points out that run number la provides the desired combination in all phases. Regardless of the internal changes, little change is noted in the selection of the optimum-terminal node.

The compare logic embedded in the model appears to filter out the effect of the conditions selected regardless of the combinations of distributions which lead to these factors. For example, in phase I the improved radar operating in an ECM environment is the selected combination in run numbers 1, 1a, 2, and 3 and nearly even in run number 4. High altitude, low visibility manual radar assisted tracking is the selected combination at the end of phase II. The separate but on line doctrine is a clear winner in phases III and IV. In both these phases the other two doctrines compete evenly for second place. With essentially normal and uniform distributions, the only cause for project failure (realization of node FAILP) was the multiple failure of test paths for individual components. When exponential, normal, and gamma performance distributions were combined, a small percentage of project failures occurred through the failure of the employment doctrine test to meet minimum standards (initiation of arc FAAP).

With only one exception, none of the distributions compiled by VERT for the Falcon runs are markedly skewed; however, numerous incidents of bimodal distributions were identified. The mean, mode, and standard deviation increase successively in run numbers 1, 2, and 3 followed by a marked decrease in run number 4. There is no obvious pattern to Pearson's measure of skewness. Only the composite terminal node shows significant kurtosis. The compilation of normal data resulted in a markedly leptokurtic (peaked) curve. At the other extreme the combination of distributions represented in run number 4 resulted in a markedly platykurtic (flat) curve for the composite terminal node.

The coefficient of variation indicates only scattered instances of widely dispersed distributions. If a pattern persists here, it is that the uniform data in run number 2 and the mixed distribution data in run number 4 are spread to a greater degree than the normal data of run number 1 and the mixed distribution data in run number 3. It is obvious from Table 15 that risk in the Falcon model is sensitive to the mean of the distribution. It also appears that deviations from the norm increase the risk that the Falcon operational test will not achieve desired standards.

Another useful tool provided by VERT output is the cumulative histogram. Figure 9 is an illustration of this output from run number 1. Through this graph the analyst can ascertain the risk associated with specific values. Figure 9 indicates, for example, that there is an 80 percent chance that the cost of the Falcon operational test using normal data will be less than $177,623 using 90 aircraft sorties, hence, there is a 20 percent risk that it will exceed that value.

Yet another useful tool provided by VERT are the correlation graphs. Figure 10 is an example of such a graph from run number 4. It is interesting to note here that although time and performance have no dependency relationships,

OVERALL COST FOR THE COMPOSITE TERMINAL NODE

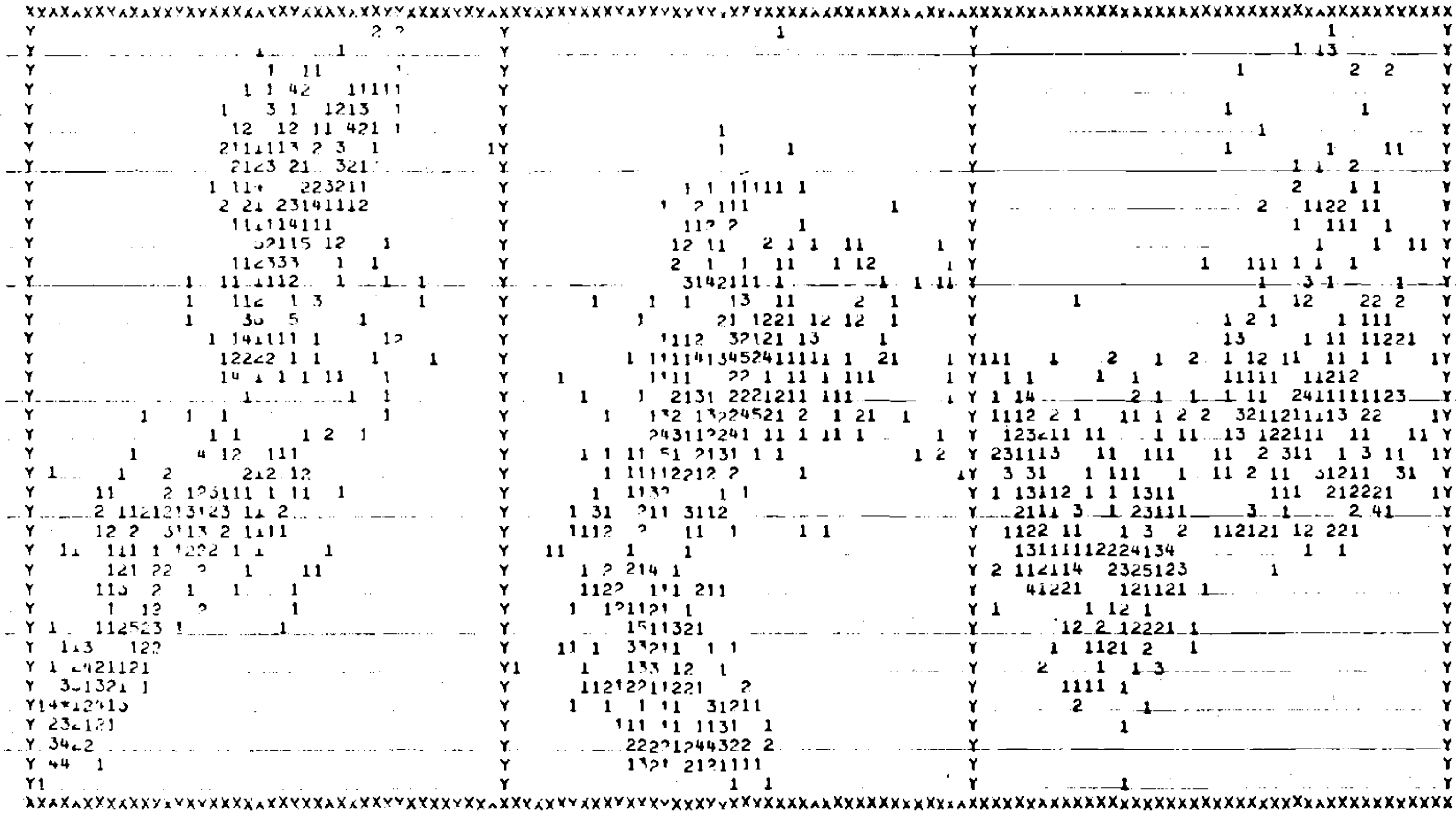
```
 FALCON RUN NUMBR = 2
         RFD   .05  .10  .15  .20  .25
 31.5764 I----I----I----I----I----I MIN
         I                         .000
 31.5764 I
         I                         .004
 38.8737 I
         I                         .000
 46.1810 I
         I                         .002
 53.4833 I
         I                         .006
 60.7856 I
         I                         .008
 68.0879 I
         I                         .010
 75.3903 I
         I                         .004
 82.6926 I
         I                         .004
 89.9949 I
         I                         .002
 97.2972 I
         I                         .000
104.5995 I
         I                         .002
111.9018 I
         I                         .000
119.2042 I
         I                         .002
126.5065 I
         I                         .000
133.8088 I
         I                         .008
141.1111 I
         I*******                  .072
148.4134 I
         I********                 .078
155.7157 I
         I***************          .156
163.0181 I
         I****************         .162
170.3204 I
         I***************          .160
177.6227 I
         I************             .120
184.9250 I
         I**********               .098
192.2273 I
         I*******                  .066
199.5296 I
         I**                       .024
```

```
         CFD  .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
 31.5764 I----I----I----I----I----I----I----I----I----I----I MIN
         I                                                   .000
 31.5764 I
         I                                                   .004
 38.8787 I
         I                                                   .004
 46.1810 I
         I                                                   .006
 53.4833 I
         I*                                                  .012
 60.7856 I
         I*                                                  .020
 68.0879 I
         I*                                                  .030
 75.3903 I
         I**                                                 .034
 82.6926 I
         I**                                                 .038
 89.9949 I
         I**                                                 .040
 97.2972 I
         I**                                                 .040
104.5995 I
         I**                                                 .042
111.9018 I
         I**                                                 .042
119.2042 I
         I**                                                 .044
126.5065 I
         I**                                                 .044
133.8088 I
         I***                                                .052
141.1111 I
         I******                                             .124
148.4134 I
         I**********                                         .202
155.7157 I
         I******************                                 .358
163.0181 I
         I**************************                         .520
170.3204 I
         I**********************************                 .680
177.6227 I
         I****************************************           .800
184.9250 I
         I*********************************************      .898
192.2273 I
         I************************************************   .964
199.5296 I
         I*************************************************  .988
```

Figure 9. Cost Histogram Run Number 1

CORRELATIONS AND X-Y PLOTS FOR PRECEDING NODE
(* MEANS PLOTTING 10 OR MORE POINTS PER UNIT CELL)

TIME(Y) VS COST(X) R = .84 COST(Y) VS PERFORMANCE(X) R = .45 PERFORMANCE(Y) VS TIME(X) R = .51



NOTE---PATH COST WAS USED IN THIS PLOT

Figure 10. Correlation Plots Run Number 4

they appear to follow an exponential pattern. Perhaps the decision-maker will elect to extend the time allocation to gain the exponential increase in performance.

This analysis is by no means complete, but merely illustrative of the versatility of VERT as a tool to analyze a network model. Fifteen trial runs were used from which the five examples were chosen to illustrate here. Further investigations are necessary involving model changes, sensitivity to the end points, and other individual distribution and dependency changes. The extensive array of logic and transformations permits the analyst to explore any number of linear or nonlinear, univariate, or multivariate parameter relationships. Basic to this entire discussion, however, is the fact that the analyst, test designer, or test evaluator can now focus his efforts on the accuracy of the activity or subtest inputs in lieu of the more massive problems of the interrelationships of the parameters or the aggregation of these variables into a total profile. Falcon has shown quite clearly that complex interactions in test design can be modeled and analyzed by VERT.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Operational tests are a subactivity of the total material acquisition development cycle. They contain within this subactivity a number of additional activities, subtests, or subprograms. Each of these activities or subtests has related functional values. These values may be deterministic, stochastic, or some mathematical transformation of a value computed in an earlier activity. These activities lead to milestones or events and the outcome of the operational test can be represented by a set of successful and a set of unsuccessful events. This set of conditions describes a stochastic network. Of the network analysis tools, network simulation affords the greatest versatility and flexibility in modeling this set of conditions. Of the family of network simulation programs two programs have evolved as useful analysis tools to assess risk, SOLVNET and VERT.

VERT's extensive output, redimensioning capability, flexible node logic, extensive number of probability distributions, and mathematical transformations and simultaneous accumulation of the three principal dimensions of time, cost, and performance into the "fourth dimension" risk make it the best choice for modeling extensive problems in a decision environment. SOLVNET is better suited to problems in the time/cost plane which are characterized by extensive dependency interactions.

The extension of this concept to the conduct of risk analysis in the design and conduct of an operational test is both feasible and practical. A network analysis tool such as VERT "removes the inductive headaches from modeling component interaction. These operands enable the user to explore conditional nonlinear multivariate situations which defy ready mathematical analysis" [34]. Test plans and designs fall neatly in line with little manipulation of these operands in building a model to assess test design risk. The use of a formalized tool to assess risk would generate interest among the test designers and evaluators in analyzing data inputs. During the course of the analysis:

1. Potential problems can be identified.
2. The risk consequences of a subtest failure can be assessed.
3. Low impact tests can be identified.
4. High impact tests can be identified.
5. The sufficiency of test projections for time, cost, and associated performance allocations can be determined.

In summary, the objective of a risk analysis study in operational testing is to create a model of the operational test and exercise the model with realistic inputs. The results of this analysis provide the operational test decision-maker with a basis to compare competing test alternatives.

Recommendations

1. The existing VERT source program is logically invalid when converted to a smaller bit-size computer than the IBM 360/65. It is a simple matter to incorporate the changes in subroutines DOARC and GAM outlined in Appendix III into the VERT source program. These simple changes should be included in future published versions of VERT.

2. VERT has an extensive list of transformations which permit the analyst to model mathematical relationships which may exist within the network. It is possible with successive combinations of node logic to express dependency relationships in an explicit manner. It would be useful to investigate the incorporation of additional dependency logic to facilitate the expression of these relationships. A provision should be made to express dependency transformations on an arc or node in the event that it was a failure earlier in the network.

3. SOLVNET is limited to two parameters; and, one of these must be dependent on the other. This limits its usefulness in representing many decision models which arise in operational testing. An expansion of SOLVNET to include additional independent parameters would significantly

improve the number of applications which could be modeled and analyzed by this program.

APPENDIX I

SOLVNET OUTPUT

The following pages contain computer generated SOLVNET output. The output represents Phases I and II of the Falcon Operational Test. The SOLVNET program does not permit the user to select output options. The output presented here is typical of SOLVNET and is listed as follows:

1. Arc Index of Criticality.
2. Graph of Completion Costs for Terminal Node N19.
3. Graph of Completion Times for Terminal Node N19.
4. Bivariate Graph for Terminal Node N19.
5. Graph of Completion Times for All Nodes.
6. Graph of Completion Costs for All Nodes.
7. Bivariate Graph for All Nodes.
8. Graph of Node Probabilities.

CRITICAL PATH INDICES

ARC	INDEX OF CRITICALITY
ORGT	1.000
IMPR	.912
RADR	.088
IECO	.896
IECF	.016
RECO	.086
RECF	.002
BDOI	.896
BDFI	.016
BDOR	.086
BDFR	.002
ENDI	.896
ENDD	.016
ENDR	.086
ENDB	.002
LAST	.726
MANT	.274
LTHA	.054
LTMA	.672
MTHA	.026
MTMA	.248
TSPL	.054
TSML	.672
TSPM	.026
TSMM	.248
HVLA	.714
LVLA	.012
HVMA	.274
BTLA	.714
BTLB	.012
BTMA	.274
MPE1	.714
MPE2	.012
MPE3	.274

GRAPH OF COMPLETION COSTS FOR TERMINAL NODE N19

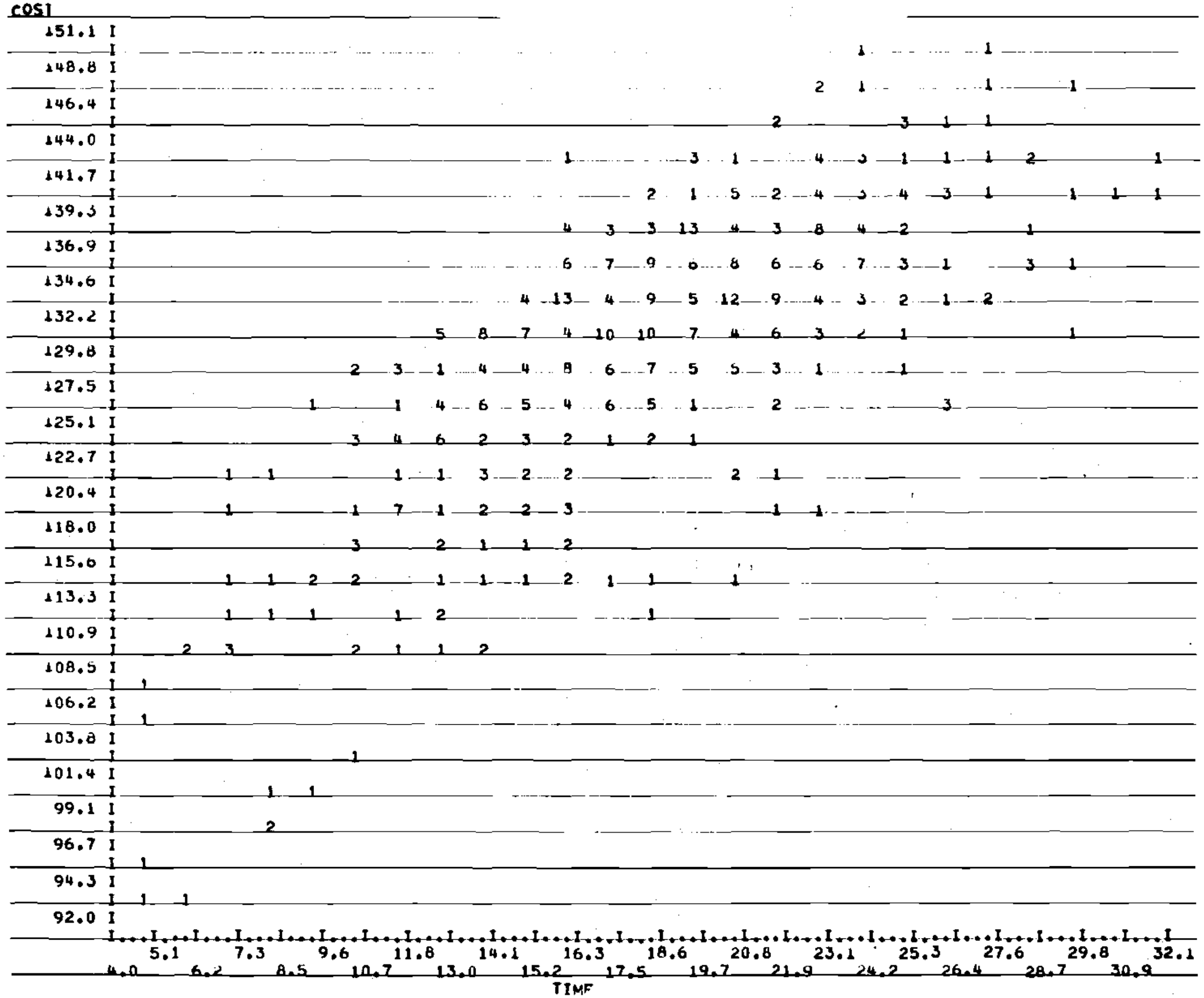
```
1.00u I       151.1 I
                    I=I
 .99u I       148.8 I=I .004
                    I=I
 .98u I       146.4 I=I .010
                    I=I
 .97< I       144.0 I=I .014
                    I==I
 .93o I       141.7 I==I .036
                    I====I
 .88u I       139.3 I====I .056
                    I========I
 .79u I       136.9 I========I .090
                    I============I
 .664 I       134.6 I============I .126
                    I============I
 .52o I       132.2 I============I .136
                    I============I
 .39< I       129.8 I============I .136
                    I========I
 .29< I       127.5 I========I .100
                    I======I
 .21o I       125.1 I======I .076
                    I====I
 .16u I       122.7 I====I .048
                    I==I
 .14u I       120.4 I==I .028
                    I==I
 .10< I       118.0 I==I .038
                    I=I
 .084 I       115.6 I=I .018
                    I==I
 .05o I       113.3 I==I .028
                    I=I
 .04< I       110.9 I=I .014
                    I==I
 .02u I       108.5 I==I .022
                    I=I
 .01o I       106.2 I=I .002
                    I=I
 .01o I       103.8 I=I .002
                    I=I
 .014 I       101.4 I=I .002
                    I=I
 .01u I        99.1 I=I .004
                    I=I
 .00u I        96.7 I=I .004
                    I=I
 .004 I        94.3 I=I .002
                    I=I
 .00u I        92.0 I=I .004
                    ---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                            .1        .2        .3        .4        .5        .6        .7        .8        .9       1.0

THE MEAN IS      130.29  THE STAN DEV IS       9.18  THE MEDIAN IS      131.71  THE MODE IS      133.38
```

```
   CP
 1.000 I         32.1 I
                      I=I
  .996 I         30.9 I=I .004          GRAPH OF COMPLETION TIMES FOR TERMINAL NODE N19
                      I=I
  .994 I         29.8 I=I .002
                      I=I
  .986 I         28.7 I=I .008
                      I=I
  .974 I         27.6 I=I .012
                      I=I
  .960 I         26.4 I=I .014
                      I=I
  .940 I         25.3 I=I .020
                      I==I
  .906 I         24.2 I==I .034
                      I====I
  .856 I         23.1 I====I .048
                      I=======I
  .796 I         21.9 I=======I .066
                      I=======I
  .726 I         20.8 I=======I .070
                      I=========I
  .630 I         19.7 I=========I .084
                      I=========I
  .554 I         18.6 I=========I .084
                      I=========I
  .456 I         17.5 I=========I .098
                      I=======I
  .380 I         16.3 I=======I .076
                      I===========I
  .276 I         15.2 I===========I .102
                      I====I
  .220 I         14.1 I====I .058
                      I====I
  .166 I         13.0 I====I .058
                      I====I
  .114 I         11.8 I====I .048
                      I==I
  .070 I         10.7 I==I .036
                      I==I
  .050 I          9.6 I==I .028
                      I=I
  .040 I          8.5 I=I .010
                      I=I
  .026 I          7.3 I=I .012
                      I=I
  .014 I          6.2 I=I .014
                      I=I
  .006 I          5.1 I=I .006
                      I=I
  .000 I          4.0 I=I .008
                      ---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                               .1        .2        .3        .4        .5        .6        .7        .8        .9       1.0

 THE MEAN IS      17.65  THE STAN DEV IS       4.99  THE MEDIAN IS      17.96  THE MODE IS      15.77
```

BIVARIATE GRAPH FOR TERMINAL NODE N19



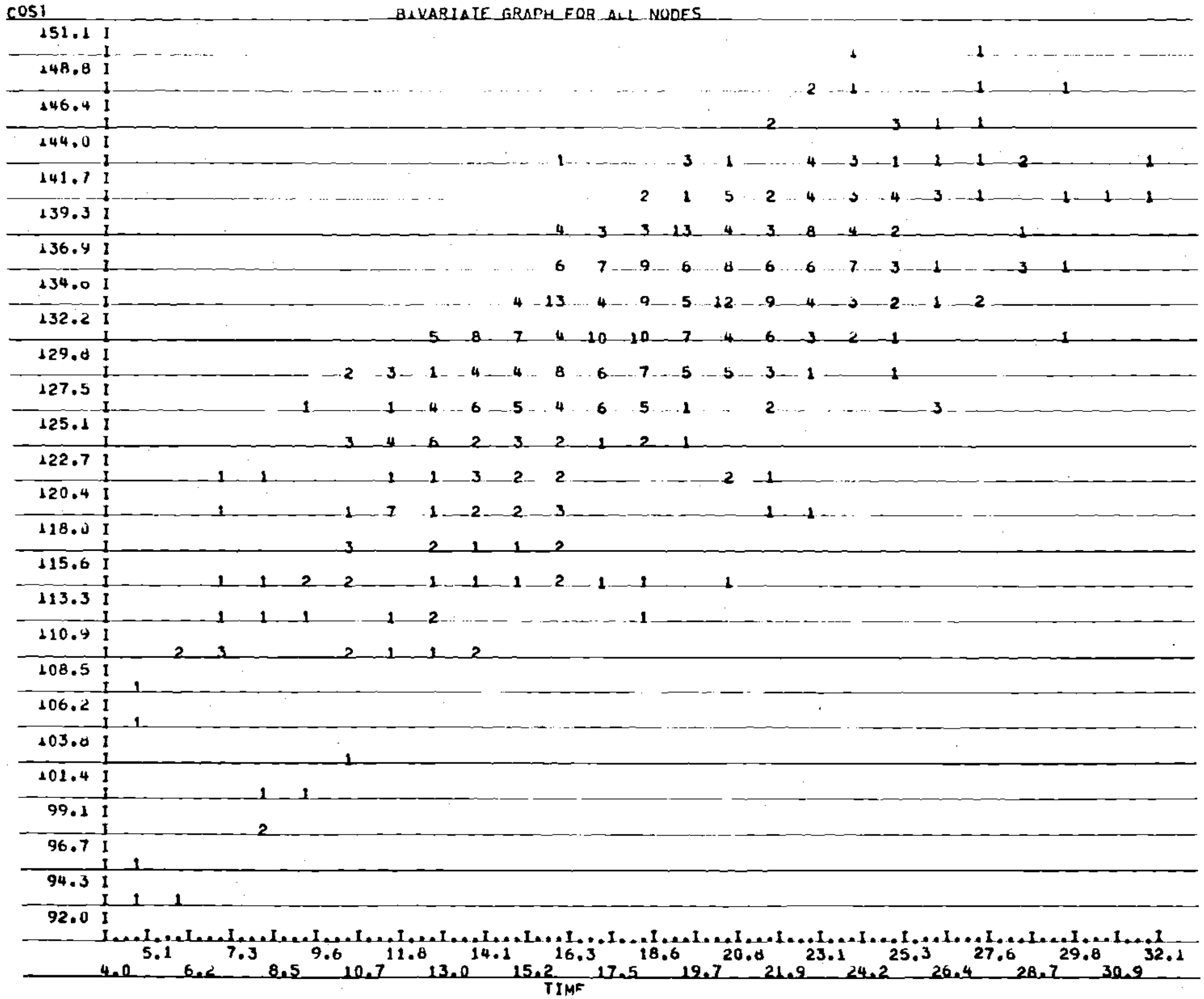
GRAPH OF COMPLETION TIMES FOR ALL NODES

```
  CP
1.000 I   32.1 I
               I=I
 .996 I   30.9 I=I .004
               I=I
 .994 I   29.8 I=I .002
               I=I
 .986 I   28.7 I=I .008
               I=I
 .974 I   27.6 I=I .012
               I=I
 .960 I   26.4 I=I .014
               I=I
 .940 I   25.3 I=I .020
               I==I
 .906 I   24.2 I==I .034
               I====I
 .858 I   23.1 I====I .048
               I=======I
 .792 I   21.9 I=======I .066
               I=======I
 .722 I   20.8 I=======I .070
               I=========I
 .638 I   19.7 I=========I .084
               I=========I
 .554 I   18.6 I=========I .084
               I=========I
 .456 I   17.5 I=========I .098
               I=======I
 .380 I   16.3 I=======I .076
               I===========I
 .278 I   15.2 I===========I .102
               I====I
 .220 I   14.1 I====I .058
               I====I
 .162 I   13.0 I====I .058
               I====I
 .114 I   11.8 I====I .048
               I==I
 .078 I   10.7 I==I .036
               I==I
 .050 I    9.6 I==I .028
               I=I
 .040 I    8.5 I=I .010
               I=I
 .028 I    7.3 I=I .012
               I=I
 .014 I    6.2 I=I .014
               I=I
 .008 I    5.1 I=I .006
               I=I
 .000 I    4.0 I=I .008
               ---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                        .1        .2        .3        .4        .5        .6        .7        .8        .9       1.0
```

THE MEAN IS 17.65 THE STAN DEV IS 4.99 THE MEDIAN IS 17.96 THE MODE IS 15.77

```
  CP
1.000 I      151.1 I                GRAPH OF COMPLETION COSTS FOR ALL NODES
                   I=I
 .996 I      148.8 I=I .004
                   I=I
 .986 I      146.4 I=I .010
                   I=I
 .972 I      144.0 I=I .014
                   I==I
 .936 I      141.7 I==I .036
                   I====I
 .880 I      139.3 I====I .056
                   I=========I
 .790 I      136.9 I=========I .090
                   I=============I
 .664 I      134.6 I=============I .126
                   I=============I
 .528 I      132.2 I=============I .136
                   I=============I
 .392 I      129.8 I=============I .136
                   I=========I
 .292 I      127.5 I=========I .100
                   I=======I
 .216 I      125.1 I=======I .076
                   I====I
 .168 I      122.7 I====I .048
                   I==I
 .140 I      120.4 I==I .028
                   I==I
 .102 I      118.0 I==I .038
                   I=I
 .084 I      115.6 I=I .018
                   I==I
 .056 I      113.3 I==I .028
                   I=I
 .042 I      110.9 I=I .014
                   I==I
 .020 I      108.5 I==I .022
                   I=I
 .018 I      106.2 I=I .002
                   I=I
 .016 I      103.8 I=I .002
                   I=I
 .014 I      101.4 I=I .002
                   I=I
 .010 I       99.1 I=I .004
                   I=I
 .006 I       96.7 I=I .004
                   I=I
 .004 I       94.3 I=I .002
                   I=I
 .000 I       92.0 I=I .004
                    ---------I---------I---------I---------I---------I---------I---------I---------I---------I---------I
                             .1        .2        .3        .4        .5        .6        .7        .8        .9       1.0

THE MEAN IS     130.29  THE STAN DEV IS       9.18  THE MEDIAN IS     131.71  THE MODE IS     133.38
```


COST
BIVARIATE GRAPH FOR ALL NODES
151.1
148.8
146.4
144.0
141.7
139.3
136.9
134.6
132.2
129.8
127.5
125.1
122.7
120.4
118.0
115.6
113.3
110.9
108.5
106.2
103.8
101.4
99.1
96.7
94.3
92.0
5.1 7.3 9.6 11.8 14.1 16.3 18.6 20.8 23.1 25.3 27.6 29.8 32.1
4.0 6.2 8.5 10.7 13.0 15.2 17.5 19.7 21.9 24.2 26.4 28.7 30.9
TIME

```
    I==========================================================================================I
N19 I==========================================================================================I.000
    I
    I
     ----------I----------I----------I----------I----------I----------I----------I----------I----------I----------I
               .1         .2         .3         .4         .5         .6         .7         .8         .9        1.0
```

GRAPH OF NODE PROBABILITIES

APPENDIX II

VERT OUTPUT

The following pages contain computer generated VERT output. The VERT program permits the user to select from a list of option combinations. The sample output selected here is from the Falcon Operational Test, run number one using normal data. The data output represented here is typical and represents:

1. Heading and partial data listing - output option 3.
2. Iterations number one and two - output option 3.
3. An iteration by iteration summary - output option 2.
4. Graph of Network Time for Node BEGTK - output option 2.
5. Graph of Path Cost for Node BEGTK - output option 2.
6. Graph of Overall Cost for Node BEGTK - output option 2.
7. Graph of Path Performance for Node BEGTK - output option 2.
8. Graph of Network Time for Node TERMT - output option 2.
9. Graph of Path Cost for Node TERMT - output option 2.
10. Graph of Overall Cost for Node TERMT - output option 2.
11. Graph of Path Performance for Node TERMT - output option 2.
12. Graph of Network Time for Node Success - output option 2.

13. Graph of Path Cost for Node Success - option 2.

14. Graph of Overall Cost for Node Success - option 2.

15. Graph of Path Performance for Node Success - option 2.

16. Correlations and x-y Plots for Node Success - option 2.

17. Graph of Network Time for Node FAILP - option 2.

18. Graph of Path Cost for Node FAILP - option 2.

19. Graph of Overall Cost for Node FAILP - option 2.

20. Graph of Path Performance for Node FAILP - option 2.

21. Correlations and x-y Plots for Node FAILP - option 2.

22. Graph of Network Time for the Composite Terminal Node - option 2.

23. Graph of Path Cost for the Composite Terminal Node - option 2.

24. Graph of Overall Cost for the Composite Terminal Node - option 2.

25. Graph of Path Performance for the Composite Terminal Node - option 2.

26. Correlations and x-y Plots for the Composite Terminal Node - option 2.

27. Optimum Terminal Node Index - option 2.

28. Arcs Critical-optimum Path Index - option 2.

29. Nodes Critical-Optimum Path Index - option 2.

30. Terminal Node Summary - option 0.

```
FALCON - RUN NO 1 - OUTPUT OPTION 3 - NORMAL DATA

RUN IDENTIFICATION CARD OPTION-----------------------------------------------      1

TYPE OF RUN OPTION-----------------------------------------------------------      0

TYPE OF OUTPUT OPTION--------------------------------------------------------      3

COSTING AND PRUNNING OPTION--------------------------------------------------      1

INITIAL SEED-----------------------------------------------------------------  96581

NUMBER OF ITERATIONS---------------------------------------------------------     15

YEARLY INTEREST RATE USED FOR PRESENT VALUE DISCOUNTING----------------------    .00

TIME FACTOR WHICH CONVERTS PROGRAM TIME TO A YEARLY BASIS--------------------    .00
                                                TIME       COST PERFORMANCE

TERMINAL NODE SELECTION WEIGHTS                  .00        .00        1.00

CRITICAL - OPTIMUM PATH WEIGHTS                  .00        .00        1.00

INITIAL PROBLEM VALUES                           .00        .00         .00


ORGT    START    BEGID    1.0  OGANIZE TEST DIRECTORATE
ORGT    DTIME 1    2.0         .5         1.5
ORGT    DCOST 1    3.0         10.0       19.0      15.0
IMPR    BEGID    IMPSC    1.0  IMPROVED RADAR DETECTION
IMPR    DTIME 1    4.0         .5         1.5       1.0       .15
IMPR    RCOST 1  1STIMPR     K 10.0    K 1.0
IMPR    DPERF 1    4.0         .5         35.0      20.0      8.0
RADR    BEGID    RADSC    1.0  BASIC RADAR DETECTION
RADR    DTIME 1    4.0         .5         1.5       1.0       .15
RADR    RCOST 1  1STRADR     K 10.0    K 1.0
RADR    DPERF 1    4.0         .3         30.0      18.0      8.0
FADT    IMPSC    FAIL     1.0  FAIL TO DETECT GE 5 K IMPROVE
IECO    IMPSC    MIIDI    .90  ECM ON IMPROVED RADAR
IECO    FILT1 1                                               5.0       50.0
IECO    RCOST 1  1SCIMPR     K .5      K 1.0
IECO    DPERF 1    4.0       -10.0      -.1       -5.0       3.0
IECF    IMPSC    MIIDI    .95  ECM OFF IMPROVED RADAR
IECF    FILT1 1                                               5.0       50.0
FADR    RADSC    FAIL     1.0  FAIL TO DETECT GE 5 K REGULAR
RECO    RADSC    MIIDR    .90   ECM ON REGULAR
RECO    FILT1 1                                               5.0       50.0
RECO    RCOST 1  1SCRADR     K .5      K 1.0
RECO    DPERF 1    4.0       -11.0      -1.0      -5.0       3.0
RECF    RADSC    MIIDR    .95  ECM OFF REGULAR
RECF    FILT1 1                                               5.0       50.0
FAII    MIIDI    FAIL     1.0  FAIL COMPARISON RELIABILITY IMPROVED
BDOI    MIIDI    BESTI    1.0  SUCCESS ECM ON IMPROVED
BDFI    MIIDI    BESTI    1.0  SUCCESS ECM OFF IMPROVED
FAIR    MIIDR    FAIL     1.0  FAIL COMPARISON RELIABILITY REGULAR
```

ITERATION NO. = 1 TERMINAL NODE = SUCCESS STARTING SEED = 96581 (COST PRESENT VALUE ADJUSTED IF REQUESTED)

RC DATA/ NAME	STATUS	TIME PRIMARY	TIME CUMULATIVE	PATH COST PRIMARY	PATH COST CUMULATIVE	PERFORMANCE PRIMARY	PERFORMANCE CUMULATIVE
ORGT	4	.51	.51	14.50	14.50	.00	.00
IMPR	4	1.17	1.68	11.74	26.24	25.72	25.72
RADR	4	.76	1.27	7.57	22.07	12.20	12.20
IECO	4	.00	1.68	5.87	32.11	-7.06	18.67
IECF	3	.00	1.68	.00	26.24	.00	25.72
RECO	4	.00	1.27	3.79	25.86	-6.09	6.11
RECF	3	.00	1.27	.00	22.07	.00	12.20
BOOI	4	.00	1.68	.00	32.11	.00	18.67
BOOR	3	.00	1.27	.00	25.86	.00	6.11
ENDI	4	.00	1.68	.00	32.11	.00	18.67
LAST	4	.76	2.44	7.61	39.72	-.55	18.12
MANT	4	2.60	4.29	26.03	58.14	-2.22	16.44
LTHA	4	.00	2.44	.00	39.72	-.76	17.36
LTMA	3	.00	2.44	1.52	41.24	.19	18.31
MTHA	4	.00	4.29	.00	58.14	-.99	15.45
MTMA	3	.00	4.29	5.21	63.34	.07	16.51
TSPL	4	.00	2.44	.00	39.72	.00	17.36
TSPM	4	.00	4.29	.00	58.14	.00	15.45
HVLA	3	.00	2.44	.00	39.72	-1.81	15.55
LVLA	4	.00	2.44	.76	40.48	-3.78	13.58
HVMA	2	.00	4.29	.00	58.14	-.17	15.28
LVMA	2	.00	4.29	2.60	60.74	-2.00	13.45
BTLB	4	.00	2.44	.00	40.48	.00	13.58
FAVM	4	.00	4.29	.00	60.74	.00	.00
MPE2	4	.00	2.44	.00	40.48	.00	13.58
LOOC	4	.00	2.44	22.33	62.81	-13.58	.00
RTDO	4	1.51	3.95	15.07	77.88	12.08	12.08
RSDO	4	1.50	3.94	14.98	77.79	22.44	22.44
RMDO	4	1.52	3.96	15.21	78.02	23.46	23.46
WIDT	4	.00	3.95	.00	77.88	-4.85	7.23
WFDT	4	.00	3.95	.00	77.88	-.35	11.73
WIDS	4	.00	3.94	.00	77.79	-6.92	15.51
WFDS	4	.00	3.94	.00	77.79	2.98	25.42
WIDM	4	.00	3.96	.00	78.02	-6.01	17.44
WFDM	4	.00	3.96	.00	78.02	.67	24.12
VRCO	3	.00	3.96	.00	78.02	-6.43	11.01
EVTD	3	.00	3.95	.00	77.88	-3.44	3.44
EVSD	4	.00	3.94	.00	77.79	-9.25	9.25
EVMD	4	.00	3.96	.00	78.02	-12.06	12.06
LTD2	4	.00	3.96	.00	77.79	-.60	8.64
LTD3	2	.00	3.96	.00	78.02	-.48	11.58
BES2	4	2.86	6.83	28.64	106.43	.00	8.64
FAILTRN	4	.00	4.29	.00	60.74	.00	.00
STOP	4	.00	6.83	.00	106.43	.00	8.64

NODE DATA

NAME	STATUS	TIME	PATH COST	PERFORMANCE
START	3	.00	.00	.00
BEGID	3	.64	16.37	.00
IMPSC	3	1.72	27.14	31.30
RADSC	3	1.54	25.40	18.28
MIIDI	3	1.72	32.52	28.66
MIIDR	3	1.54	29.91	15.69
BESTI	3	1.72	46.05	19.56
BEGTK	3	1.72	32.52	26.02
LASYS	3	3.89	54.26	25.09
MTSYS	3	3.05	45.81	25.72
MITKL	3	3.89	58.61	24.32
MITKM	3	3.05	48.47	26.02
LAWTR	3	3.89	54.26	24.28
MAWTR	3	3.05	48.47	26.02
MILTV	3	3.89	56.43	20.14
MIMTV	3	3.05	49.79	24.75
BESTK	3	3.89	73.71	20.90
TERMT	3	3.89	49.79	23.71
BEDOC	3	3.89	65.02	.00
TUGDO	3	5.48	80.87	11.98
SEPDO	3	5.30	79.07	23.15
MODDO	3	5.24	78.47	18.42
VACOG	3	5.24	78.47	14.01
MXRDT	3	5.48	80.87	6.52
MARDS	3	5.30	79.07	16.91
MARDO	3	5.24	78.47	18.58
TESTD	3	5.48	108.36	7.00
COMPD	3	5.48	92.52	8.64
ADEQD	3	8.63	109.99	8.64
SUCCESS	3	8.63	109.99	8.64

ITERATION TIME-PCOST-OCOST-PERFORMANCE = 8.63 109.99 181.69 8.64

CRITICAL PATH IF WANTED

29	ADEQD	83	STOP
28	COMPD	79	BES3
27	TESTD	75	LTD3
26	MXRDO	71	EVMD
22	MODDO	63	WFDM
19	BEDOC	54	RMDO
18	TERMT	51	LODC
17	BESTK	48	MPE4
16	MIMTV	44	BTMB
14	MAWTR	38	LVMA
12	MITKM	34	TSMM
10	MTSYS	28	MTMA
8	BEGTK	22	MANT
7	BESTI	17	ENDI
5	MIIDI	11	BDOI
3	IMPSC	5	IECO
2	BEGID	2	IMPR
1	START	1	ORGT

ITERATION NO. = 2 TERMINAL NODE = SUCCESS STARTING SEED = 24267779619 (COST PRESENT VALUE ADJUSTED IF REQUESTED)

RC DATA/ NAME	STATUS	TIME PRIMARY	TIME CUMULATIVE	PATH COST PRIMARY	PATH COST CUMULATIVE	PERFORMANCE PRIMARY	PERFORMANCE CUMULATIVE
ONGT	4	.64	.64	16.37	16.37	.00	.00
IMPR	4	1.06	1.72	10.76	27.14	31.30	31.30
RADR	4	.90	1.54	9.02	25.40	18.28	18.28
IECO	4	.00	1.72	5.38	32.52	-5.28	26.02
IECF	3	.00	1.72	.00	27.14	.00	31.30
RECO	4	.00	1.54	4.51	29.91	-5.18	13.10
RECF	3	.00	1.54	.00	25.40	.00	18.28
BOCI	4	.00	1.72	.00	32.52	.00	26.02
BOCR	3	.00	1.54	.00	29.91	.00	13.10
ENDI	4	.00	1.72	.00	32.52	.00	26.02
LAST	4	2.17	3.89	21.74	54.26	-.92	25.09
MANT	4	1.33	3.05	13.29	45.81	-.30	25.72
LTHA	4	.00	3.89	.00	54.26	-.82	24.28
LTMA	3	.00	3.89	4.35	58.61	-.73	24.37
MTHA	2	.00	3.05	.00	45.81	-1.13	24.59
MTMA	4	.00	3.05	2.66	48.47	.30	26.02
TSPL	4	.00	3.89	.00	54.26	.00	24.28
TSMM	4	.00	3.05	.00	48.47	.00	26.02
HVLA	3	.00	3.89	.00	54.26	-2.07	22.20
LVLA	4	.00	3.89	2.17	56.43	-6.20	18.08
HVMA	3	.00	3.05	.00	48.47	-.24	25.78
LVMA	4	.00	3.05	1.33	49.79	-2.30	23.71
BTLB	3	.00	3.89	.00	56.43	.00	18.08
BTMB	4	.00	3.05	.00	49.79	.00	23.71
MPE4	4	.00	3.89	.00	49.79	.00	23.71
LODC	4	.00	3.89	15.23	65.02	-23.71	.00
RTDO	4	1.58	5.48	15.85	80.87	11.98	11.98
RSDO	4	1.40	5.30	14.05	79.07	23.15	23.15
RMDO	4	1.34	5.24	13.44	78.47	18.42	18.42
WTDT	4	.00	5.48	.00	80.87	-6.50	5.48
WFDT	4	.00	5.48	.00	80.87	1.04	13.02
WTDS	4	.00	5.30	.00	79.07	-6.29	16.86
WFDS	4	.00	5.30	.00	79.07	.05	23.20
WTDM	4	.00	5.24	.00	78.47	-4.41	14.01
WFDM	4	.00	5.24	.00	78.47	.16	18.58
VHCO	3	.00	5.24	.00	78.47	-5.53	8.48
EVTD	3	.00	5.48	.00	80.87	-3.26	3.26
EVSD	4	.00	5.30	.00	79.07	-8.46	8.46
EVMD	4	.00	5.24	.00	78.47	-9.29	9.29
LTD2	2	.00	5.48	.00	79.07	-.83	7.63
LTD3	4	.00	5.48	.00	78.47	-.65	8.64
BES3	4	3.15	8.63	31.53	109.99	.00	8.64
STOP	4	.00	8.63	.00	109.99	.00	8.64

NODE DATA

NAME	STATUS	TIME	PATH COST	PERFORMANCE
START	3	.00	.00	.00
BEGID	3	.51	14.50	.00
IMPSC	3	1.68	26.24	25.72
RADSC	3	1.27	22.07	12.20
MIIDI	3	1.68	32.11	22.19
MIIDR	3	1.27	25.86	9.16
BESTI	3	1.68	43.47	12.39
BEGTK	3	1.68	32.11	18.67
LASYS	3	2.44	39.72	18.12
MISYS	3	4.29	58.14	16.44
MITKL	3	2.44	41.24	17.84
MITKM	3	4.29	63.34	15.98
LAWTR	3	2.44	39.72	17.36
MAWTR	3	4.29	58.14	15.45
MILTV	3	2.44	40.48	14.57
MIMTV	3	4.29	60.74	.00
BESTK	3	2.44	40.48	13.58
TERMT	3	2.44	40.48	13.58
BEDOC	3	2.44	62.81	.00
TOGOO	3	3.95	77.88	12.08
SEPOO	3	3.94	77.79	22.44
MODUO	3	3.96	78.02	23.46
VRCOG	3	3.96	78.02	17.44
MXROT	3	3.95	77.88	6.88
MXRUS	3	3.94	77.79	18.49
MXRUO	3	3.96	78.02	24.12
TESTD	3	3.96	108.07	8.25
COMPD	3	3.96	93.00	8.64
ADEQD	3	6.83	106.43	8.64
FAIL	3	4.29	60.74	.00
SUCCESS	3	6.83	106.43	8.64

ITERATION TIME-PCOST-OCOST-PERFORMANCE = 6.83 106.43 183.43 8.64

CRITICAL PATH IF WANTED

29	ADEQD	83	STOP
28	COMPD	78	BES2
27	TESTD	74	LTD2
26	MXRUO	71	EVMD
22	MODUO	63	WFDM
19	BEDOC	54	RMDO
18	TERMT	51	LODC
17	BESTK	46	MPE2
15	MILTV	41	BTLB
13	LAWTR	36	LVLA
11	MITKL	30	TSPL
9	LASYS	24	LTHA
8	BEGTK	21	LAST
7	BESTI	17	ENDI
5	MIIDI	11	BDOI
3	IMPSC	5	IECO
2	BEGID	2	IMPR
1	START	1	ORGT

TERMINAL NODE	TIME	PATH COST	OVERALL COST	PERFORMANCE
1 SUCCESS	7.4651	102.6608	160.8576	8.5199
2 SUCCESS	8.4844	104.3324	166.3344	9.8309
3 SUCCESS	8.9473	106.0674	186.6986	12.0450
4 SUCCESS	9.5072	120.3973	197.3056	7.8231
5 SUCCESS	7.6059	94.9156	158.0098	7.6026
6 SUCCESS	9.7896	124.5306	201.6295	11.2778
7 SUCCESS	7.9332	112.7850	165.1986	8.8001
8 FAILF	3.2741	54.4417	68.8955	1.0287
9 SUCCESS	7.5273	99.4850	163.0135	9.9705
10 SUCCESS	7.9584	119.6204	179.0119	13.3355
11 SUCCESS	7.0522	97.4230	150.9120	7.0124
12 SUCCESS	9.2501	111.1943	172.3927	6.8313
13 SUCCESS	9.5118	118.0488	184.3764	12.4236
14 SUCCESS	9.4366	107.4265	172.6103	10.4817
15 SUCCESS	7.7413	104.6950	159.7176	9.2138
16 FAILF	2.9425	47.4851	67.8602	.0000
17 SUCCESS	7.3594	94.4665	147.2287	6.6080
18 SUCCESS	7.0635	93.4758	144.8030	6.4044
19 SUCCESS	7.3843	96.8445	166.8987	8.0945
20 SUCCESS	9.4368	97.1609	182.6641	8.0288
21 SUCCESS	6.5498	115.2495	180.3866	10.0541
22 SUCCESS	8.2957	99.7071	170.3733	10.5203
23 SUCCESS	8.4806	104.8939	169.6313	10.1564
24 SUCCESS	7.9695	108.8837	170.3814	11.1146
25 SUCCESS	7.8870	104.5914	162.7672	10.6673
26 SUCCESS	8.1237	94.1931	155.8675	13.6917
27 SUCCESS	9.3265	103.9711	169.4776	9.4795
28 SUCCESS	9.0267	101.9083	166.5469	10.7806
29 SUCCESS	7.6369	98.6419	154.2934	11.5191
30 SUCCESS	7.3194	96.5127	144.1127	9.7329
31 SUCCESS	7.4950	96.5424	161.1619	9.2301
32 SUCCESS	8.8994	101.7199	170.7628	10.3525
33 SUCCESS	6.8078	81.2882	144.2864	6.2232
34 SUCCESS	8.8096	108.5497	164.1314	9.2844
35 SUCCESS	8.3424	101.0742	164.3461	9.2684
36 SUCCESS	9.7582	114.3415	198.9296	8.3015
37 FAILF	3.2975	47.5994	71.8114	1.5301
38 SUCCESS	9.6002	98.9284	183.2077	8.7523
39 SUCCESS	7.2861	105.7530	157.5559	9.4272
40 SUCCESS	9.5958	121.3509	184.2743	9.2006
41 SUCCESS	7.9073	112.5872	170.4126	8.9875
42 SUCCESS	7.7578	107.6144	178.1884	10.4434
43 SUCCESS	7.3566	96.5755	167.3224	7.1266
44 SUCCESS	9.6939	123.6525	179.0009	12.4057
45 SUCCESS	7.0181	103.6622	161.7542	9.4176
46 FAILF	1.6234	37.9191	37.9191	4.3995
47 SUCCESS	8.1604	99.0570	171.0494	9.1945
48 SUCCESS	8.2864	113.4133	193.0784	9.5920
49 SUCCESS	7.9448	105.7067	173.1912	8.5407
50 SUCCESS	7.6728	86.2622	146.8446	9.6473
51 SUCCESS	8.4854	109.1834	164.6756	10.9545
52 SUCCESS	7.7664	94.8697	147.9501	9.8367
53 SUCCESS	8.4402	97.7674	173.6211	7.6480

NETWORK TIME FOR NODE 6EGTK

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

	RFD (.05 .10 .15 .20 .25)	CFD (.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0)
1.3492	MIN	MIN
	.000	.000
1.3492		
	.002	.002
1.4089		
	.010	.012
1.4686		
	.020	.032
1.5283		
	.024	.056
1.5879		
	.032	.088
1.6476		
	.040	.129
1.7073		
	.054	.183
1.7670		
	.048	.231
1.8266		
	.060	.291
1.8863		
	.062	.353
1.9460		
	.070	.424
2.0057		
	.042	.466
2.0653		
	.076	.542
2.1250		
	.056	.598
2.1847		
	.060	.659
2.2443		
	.072	.731
2.3040		
	.062	.793
2.3637		
	.054	.847
2.4234		
	.046	.894
2.4830		
	.044	.938
2.5427		
	.028	.966
2.6024		
	.010	.976
2.6621		
	.006	.982
2.7217		
	.008	.990
2.7814		
	.006	.996
2.8411		
	.004	1.000
2.9008		
	.000	.000
2.9008	MAX	MAX

NO. OBS. = 498 MEAN = 2.0839 STD ERROR = .3132 COEF OF VARIATION = .15 KURTOSIS (BETA 2) = 2.31

MODE = 2.1029 PEARSONIAN SKEW = .06

PATH COST FOR NODE BEGTV
FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

Class boundary	RFD (.05 .10 .15 .20 .25)	CFD (.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0)
19.2522	MIN	MIN
	.000	.000
19.2522		
	.008	.008
19.9493		
	.002	.010
20.6463		
	.002	.012
21.3433		
	.004	.016
22.0404		
	.016	.032
22.7374		
	.020	.052
23.4345		
	.036	.088
24.1315		
	.040	.129
24.8285		
	.054	.183
25.5256		
	.048	.231
26.2226		
	.048	.279
26.9197		
	.066	.345
27.6167		
	.076	.422
28.3137		
	.102	.524
29.0108		
	.070	.594
29.7078		
	.064	.659
30.4049		
	.076	.735
31.1019		
	.070	.805
31.7989		
	.060	.865
32.4960		
	.040	.906
33.1930		
	.022	.928
33.8901		
	.028	.956
34.5871		
	.012	.968
35.2841		
	.012	.980
35.9812		
	.006	.986
36.6782		
	.014	1.000
37.3753		
	.000	.000
37.3753	MAX	MAX

NO. OBS. = 498 MEAN = 28.8835 STD ERROR = 3.4144 COEF OF VARIATION = .12 KURTOSIS (BETA 2) = 2.79
MODE = 28.6262 PEARSONIAN SKEW = .08

OVERALL COST FOR NODE BEGTK

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

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          RFD   .05  .10  .15  .20  .25                       CFD   .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
30.8125 I----I----I----I----I----I MIN           30.8125 I----I----I----I----I----I----I----I----I----I----I MIN
        I                          .000                  I                                                   .000
30.8125 I                                        30.8125 I
        I                          .002                  I                                                   .002
31.7324 I                                        31.7324 I
        I                          .004                  I                                                   .006
32.6523 I                                        32.6523 I
        I                          .002                  I                                                   .008
33.5722 I                                        33.5722 I
        I                          .004                  I*                                                  .012
34.4921 I                                        34.4921 I
        I*                         .012                  I*                                                  .024
35.4120 I                                        35.4120 I
        I                          .008                  I**                                                 .032
36.3319 I                                        36.3319 I
        I*                         .018                  I***                                                .050
37.2517 I                                        37.2517 I
        I***                       .032                  I****                                               .082
38.1716 I                                        38.1716 I
        I****                      .040                  I******                                             .122
39.0915 I                                        39.0915 I
        I****                      .046                  I********                                           .169
40.0114 I                                        40.0114 I
        I******                    .062                  I************                                       .231
40.9313 I                                        40.9313 I
        I******                    .066                  I***************                                    .297
41.8512 I                                        41.8512 I
        I********                  .084                  I*******************                                .382
42.7710 I                                        42.7710 I
        I**********                .100                  I************************                           .482
43.6909 I                                        43.6909 I
        I*********                 .096                  I*****************************                      .578
44.6108 I                                        44.6108 I
        I*********                 .096                  I**********************************                 .675
45.5307 I                                        45.5307 I
        I*******                   .074                  I*************************************              .749
46.4506 I                                        46.4506 I
        I******                    .066                  I*****************************************          .815
47.3705 I                                        47.3705 I
        I******                    .060                  I********************************************       .876
48.2904 I                                        48.2904 I
        I****                      .046                  I**********************************************     .922
49.2102 I                                        49.2102 I
        I**                        .028                  I***********************************************    .950
50.1301 I                                        50.1301 I
        I*                         .016                  I************************************************   .966
51.0500 I                                        51.0500 I
        I*                         .010                  I*************************************************  .976
51.9699 I                                        51.9699 I
        I                          .008                  I*************************************************  .984
52.8898 I                                        52.8898 I
        I*                         .010                  I************************************************** .994
53.8097 I                                        53.8097 I
        I                          .006                  I**************************************************1.000
54.7296 I                                        54.7296 I
        I                          .000                  I                                                   .000
54.7296 I                          MAX           54.7296 I                                                   MAX
NO. OBS. =  498  MEAN =        43.7950  STU ERROR =        3.9765  COEF OF VARIATION =   .09  KURTOSIS (BETA 2) =  3.17
                 MODE =        43.5070  PEARSONIAN SKEW =   .07
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          RFD  .05  .10  .15  .20  .25                  CFD  .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
 1.9943 I----I----I----I----I----I MIN         1.9943 I----I----I----I----I----I----I----I----I----I----I MIN
        I                          .000               I                                                   .000
 1.9943 I                                      1.9943 I
        I                          .004               I                                                   .004
 3.2637 I                                      3.2637 I
        I                          .006               I*                                                  .010
 4.5332 I                                      4.5332 I
        I                          .008               I*                                                  .018
 5.8026 I                                      5.8026 I
        I                          .008               I*                                                  .026
 7.0721 I                                      7.0721 I
        I*                         .018               I**                                                 .044
 8.3415 I                                      8.3415 I
        I**                        .026               I****                                               .070
 9.6110 I                                      9.6110 I
        I***                       .034               I*****                                              .104
10.8804 I                                     10.8804 I
        I**                        .026               I*******                                            .131
12.1499 I                                     12.1499 I
        I****                      .046               I*********                                          .177
13.4193 I                                     13.4193 I
        I******                    .064               I************                                       .241
14.6888 I                                     14.6888 I
        I******                    .060               I***************                                    .301
15.9582 I                                     15.9582 I
        I******                    .064               I******************                                 .365
17.2277 I                                     17.2277 I
        I********                  .082               I**********************                             .448
18.4971 I                                     18.4971 I
        I********                  .088               I***************************                        .536
19.7666 I                                     19.7666 I
        I*****                     .058               I******************************                     .594
21.0360 I                                     21.0360 I
        I*******                   .078               I**********************************                 .673
22.3055 I                                     22.3055 I
        I******                    .066               I*************************************              .739
23.5749 I                                     23.5749 I
        I*******                   .072               I*****************************************          .811
24.8444 I                                     24.8444 I
        I*****                     .050               I*******************************************        .861
26.1138 I                                     26.1138 I
        I*****                     .054               I**********************************************     .916
27.3833 I                                     27.3833 I
        I***                       .038               I************************************************   .954
28.6527 I                                     28.6527 I
        I*                         .012               I************************************************   .966
29.9222 I                                     29.9222 I
        I**                        .020               I*************************************************  .986
31.1916 I                                     31.1916 I
        I*                         .010               I************************************************** .996
32.4611 I                                     32.4611 I
        I                          .000               I************************************************** .996
33.7305 I                                     33.7305 I
        I                          .004               I**************************************************1.000
35.0000 I                                     35.0000 I
        I                          .000               I                                                   .000
35.0000 I                          MAX        35.0000 I                                                   MAX
NO. OBS. =  498  MEAN =          19.1679  STD ERROR =          6.1202  COEF OF VARIATION =   .32  KURTOSIS (BETA 2) =  2.61
                 MODE =          18.7087  PEARSONIAN SKEW =    .08
```

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

NETWORK TIME FOR NODE TERNT

RFD .05 .10 .15 .20 .25   CFD .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Class boundary	RFD	CFD
2.0023	MIN	MIN
	.000	.000
2.0023		
	.004	.004
2.1364		
	.010	.014
2.2705		
	.008	.022
2.4046		
	.027	.049
2.5387		
	.029	.078
2.6729		
	.029	.106
2.8070		
	.045	.151
2.9411		
	.047	.198
3.0752		
	.043	.241
3.2094		
	.059	.301
3.3435		
	.061	.362
3.4776		
	.072	.434
3.6117		
	.057	.491
3.7458		
	.084	.575
3.8800		
	.065	.640
4.0141		
	.039	.679
4.1482		
	.057	.736
4.2823		
	.057	.793
4.4165		
	.035	.828
4.5506		
	.043	.871
4.6847		
	.031	.902
4.8188		
	.031	.933
4.9529		
	.022	.955
5.0871		
	.014	.969
5.2212		
	.012	.982
5.3553		
	.018	1.000
5.4894		
	.000	.000
5.4894	MAX	MAX

NO. OBS. = 489 MEAN = 3.7720 STD ERROR = .7519 COEF OF VARIATION = .20 KURTOSIS (BETA 2) = 2.40

MODE = 3.8251 PEARSONIAN SKEW = .07

```
           RFD    .05   .10   .15   .20   .25                       CFD    .1    .2    .3    .4    .5    .6    .7    .8    .9   1.0
25.1530 I-----I-----I-----I-----I-----I MIN              25.1530 I----I----I----I----I----I----I----I----I----I----I MIN
        I                               .000                     I                                                  .000
25.1530 I                                                25.1530 I
        I                               .004                     I                                                  .004
26.9643 I                                                26.9643 I
        I                               .008                     I*                                                 .012
28.7755 I                                                28.7755 I
        I***                            .033                     I**                                                .045
30.5868 I                                                30.5868 I
        I****                           .043                     I****                                              .088
32.3980 I                                                32.3980 I
        I****                           .045                     I*******                                           .133
34.2093 I                                                34.2093 I
        I*********                      .090                     I***********                                       .223
36.0206 I                                                36.0206 I
        I*********                      .090                     I****************                                  .313
37.8318 I                                                37.8318 I
        I********                       .080                     I********************                              .393
39.6431 I                                                39.6431 I
        I*********                      .092                     I************************                          .474
41.4543 I                                                41.4543 I
        I*****                          .059                     I***************************                       .534
43.2656 I                                                43.2656 I
        I********                       .086                     I*******************************                   .620
45.0769 I                                                45.0769 I
        I******                         .065                     I**********************************                .685
46.8881 I                                                46.8881 I
        I*****                          .057                     I*************************************             .742
48.6994 I                                                48.6994 I
        I****                           .049                     I****************************************          .791
50.5106 I                                                50.5106 I
        I******                         .061                     I*******************************************       .853
52.3219 I                                                52.3219 I
        I***                            .035                     I********************************************      .888
54.1332 I                                                54.1332 I
        I***                            .035                     I**********************************************    .922
55.9444 I                                                55.9444 I
        I**                             .025                     I***********************************************   .947
57.7557 I                                                57.7557 I
        I*                              .012                     I************************************************  .959
59.5669 I                                                59.5669 I
        I*                              .010                     I************************************************  .969
61.3782 I                                                61.3782 I
        I*                              .016                     I************************************************* .986
63.1895 I                                                63.1895 I
        I                               .004                     I************************************************* .990
65.0007 I                                                65.0007 I
        I                               .008                     I************************************************** .998
66.8120 I                                                66.8120 I
        I                               .000                     I************************************************** .998
68.6232 I                                                68.6232 I
        I                               .000                     I************************************************** .998
70.4345 I                                                70.4345 I
        I                               .002                     I**************************************************1.000
72.2458 I                                                72.2458 I
        I                               .000                     I                                                  .000
72.2458 I                               MAX              72.2458 I                                                  MAX
NO. OBS. =   489  MEAN =          43.1256  STD ERROR =          8.4965  COEF OF VARIATION =   .20  KURTOSIS (BETA 2) =  2.76
A MULTIMODAL DISTRIBUTION
```

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA
PATH COST FOR NODE TERMT

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

OVERALL COST FOR NODE TERMT

Boundary	RFD (.05 .10 .15 .20 .25)	CFD (.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0)
49.4585	MIN	MIN
	.000	.000
49.4585		
	.002	.002
52.8330		
	.000	.002
56.2076		
	.000	.002
59.5822		
	.004	.006
62.9568		
	.002	.008
66.3313		
	.012	.020
69.7059		
	.027	.047
73.0805		
	.047	.094
76.4551		
	.063	.157
79.8296		
	.059	.217
83.2042		
	.061	.276
86.5788		
	.096	.374
89.9534		
	.094	.468
93.3280		
	.086	.554
96.7025		
	.059	.613
100.0771		
	.084	.697
103.4517		
	.072	.769
106.8263		
	.049	.818
110.2008		
	.053	.871
113.5754		
	.039	.910
116.9500		
	.016	.926
120.3246		
	.020	.947
123.6991		
	.027	.973
127.0737		
	.018	.992
130.4483		
	.004	.996
133.8229		
	.004	1.000
137.1974		
	.000	.000
137.1974	MAX	MAX

NO. OBS. = 489 MEAN = 95.8702 STD ERROR = 15.0309 COEF OF VARIATION = .16 KURTOSIS (BETA 2) = 2.68

MODE = 89.7659 PEARSONIAN SKEW = .41

PATH PERFORMANCE FOR NODE TERMT

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

Class limit	RFD	CFD
-1.7982 (MIN)		
	.000	.000
-1.7982		
	.002	.002
-.5325		
	.004	.006
.7331		
	.014	.020
1.9988		
	.020	.041
3.2645		
	.016	.057
4.5302		
	.037	.094
5.7958		
	.037	.131
7.0615		
	.039	.170
8.3272		
	.061	.231
9.5928		
	.047	.278
10.8585		
	.057	.335
12.1242		
	.078	.413
13.3898		
	.100	.513
14.6555		
	.059	.573
15.9212		
	.061	.634
17.1868		
	.067	.701
18.4525		
	.055	.757
19.7182		
	.072	.828
20.9839		
	.065	.894
22.2495		
	.041	.935
23.5152		
	.020	.955
24.7809		
	.022	.978
26.0465		
	.014	.992
27.3122		
	.002	.994
28.5779		
	.000	.994
29.8435		
	.006	1.000
31.1092		
	.000	.000
31.1092 (MAX)		

RFD scale: .05 .10 .15 .20 .25 — CFD scale: .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

NO. OBS. = 489 MEAN = 14.6362 STD ERROR = 6.2448 COEF OF VARIATION = .43 KURTOSIS (BETA 2) = 2.44
MODE = 13.8389 PEARSONIAN SKEW = .13

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

NETWORK TIME FOR NODE SUCCESS

Interval (from – to)	RFD	CFD
5.8317 (MIN) – 5.8317	.000	.000
5.8317 – 6.0177	.002	.002
6.0177 – 6.2037	.004	.006
6.2037 – 6.3896	.008	.015
6.3896 – 6.5756	.008	.023
6.5756 – 6.7616	.013	.036
6.7616 – 6.9475	.029	.065
6.9475 – 7.1335	.042	.107
7.1335 – 7.3194	.032	.139
7.3194 – 7.5054	.055	.194
7.5054 – 7.6914	.067	.261
7.6914 – 7.8773	.076	.337
7.8773 – 8.0633	.065	.402
8.0633 – 8.2493	.057	.459
8.2493 – 8.4352	.063	.522
8.4352 – 8.6212	.086	.608
8.6212 – 8.8072	.074	.682
8.8072 – 8.9931	.057	.739
8.9931 – 9.1791	.046	.785
9.1791 – 9.3651	.053	.838
9.3651 – 9.5510	.055	.893
9.5510 – 9.7370	.046	.939
9.7370 – 9.9230	.029	.968
9.9230 – 10.1089	.015	.983
10.1089 – 10.2949	.002	.985
10.2949 – 10.4809	.004	.989
10.4809 – 10.6668	.011	1.000
10.6668 – 10.6668 (MAX)	.000	.000

NO. OBS. = 475 MEAN = 8.3467 STD ERROR = .9263 COEF OF VARIATION = .11 KURTOSIS (BETA 2) = 2.46

MODE = 8.5556 PEARSONIAN SKEW = .23

PATH COST FOR NODE SUCCESS

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

```
           FFD   .05  .10  .15  .20  .25                    CFD   .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
 81.2882 I----I----I----I----I----I MIN            81.2882 I----I----I----I----I----I----I----I----I----I----I MIN
         I                          .000                   I                                                    .000
 81.2882 I                                         81.2882 I
         I                          .002                   I                                                    .002
 83.5467 I                                         83.5467 I
         I                          .006                   I                                                    .008
 85.8052 I                                         85.8052 I
         I                          .008                   I*                                                   .017
 88.0638 I                                         88.0638 I
         I***                       .040                   I***                                                 .057
 90.3223 I                                         90.3223 I
         I***                       .036                   I*****                                               .093
 92.5809 I                                         92.5809 I
         I***                       .038                   I*******                                             .131
 94.8394 I                                         94.8394 I
         I*******                   .078                   I***********                                         .208
 97.0980 I                                         97.0980 I
         I*******                   .076                   I***************                                     .284
 99.3565 I                                         99.3565 I
         I******                    .067                   I*******************                                 .352
101.6151 I                                        101.6151 I
         I*******                   .080                   I************************                            .432
103.8736 I                                        103.8736 I
         I********                  .082                   I****************************                        .514
106.1322 I                                        106.1322 I
         I*******                   .076                   I********************************                    .589
108.3907 I                                        108.3907 I
         I*******                   .078                   I*************************************               .667
110.6493 I                                        110.6493 I
         I*******                   .080                   I*****************************************           .747
112.9078 I                                        112.9078 I
         I***                       .038                   I********************************************        .785
115.1664 I                                        115.1664 I
         I****                      .046                   I***********************************************     .832
117.4249 I                                        117.4249 I
         I***                       .038                   I************************************************    .869
119.6834 I                                        119.6834 I
         I***                       .040                   I***************************************************  .909
121.9420 I                                        121.9420 I
         I**                        .027                   I*****************************************************  .937
124.2005 I                                        124.2005 I
         I**                        .027                   I******************************************************  .964
126.4591 I                                        126.4591 I
         I*                         .015                   I*******************************************************  .979
128.7176 I                                        128.7176 I
         I                          .006                   I*******************************************************  .985
130.9762 I                                        130.9762 I
         I                          .002                   I*******************************************************  .987
133.2347 I                                        133.2347 I
         I                          .004                   I********************************************************  .992
135.4933 I                                        135.4933 I
         I                          .004                   I********************************************************  .996
137.7518 I                                        137.7518 I
         I                          .004                   I*********************************************************1.000
140.0104 I                                        140.0104 I
         I                          .000                   I                                                    .000
140.0104 I                          MAX           140.0104 I                                                    MAX
NO. OBS. =  475  MEAN =          106.4935  STD ERROR =          10.7126  COEF OF VARIATION =   .10  KURTOSIS (BETA 2) =  2.73
                 MODE =          104.4383  PEARSONIAN SKEW =    .19
```

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

OVERALL COST FOR MODE SUCCESS

	RFD (.05 .10 .15 .20 .25)	CFD (.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0)
134.1122	MIN	MIN
	.000	.000
134.1122		
	.002	.002
137.4708		
	.006	.008
140.8294		
	.015	.023
144.1881		
	.046	.069
147.5467		
	.027	.097
150.9053		
	.048	.145
154.2640		
	.072	.217
157.6226		
	.051	.267
160.9812		
	.091	.358
164.3399		
	.078	.436
167.6985		
	.084	.520
171.0571		
	.084	.604
174.4158		
	.059	.663
177.7744		
	.061	.724
181.1330		
	.051	.775
184.4917		
	.065	.840
187.8503		
	.038	.878
191.2089		
	.046	.924
194.5675		
	.021	.945
197.9262		
	.021	.966
201.2848		
	.017	.983
204.6434		
	.011	.994
208.0021		
	.002	.996
211.3607		
	.000	.996
214.7193		
	.002	.998
218.0780		
	.002	1.000
221.4366		
	.000	.000
221.4366	MAX	MAX

NO. OBS. = 475 MEAN = 171.3044 STD ERROR = 15.7210 COEF OF VARIATION = .09 KURTOSIS (BETA 2) = 2.56
MODE = 163.5338 PEARSONIAN SKEW = .49

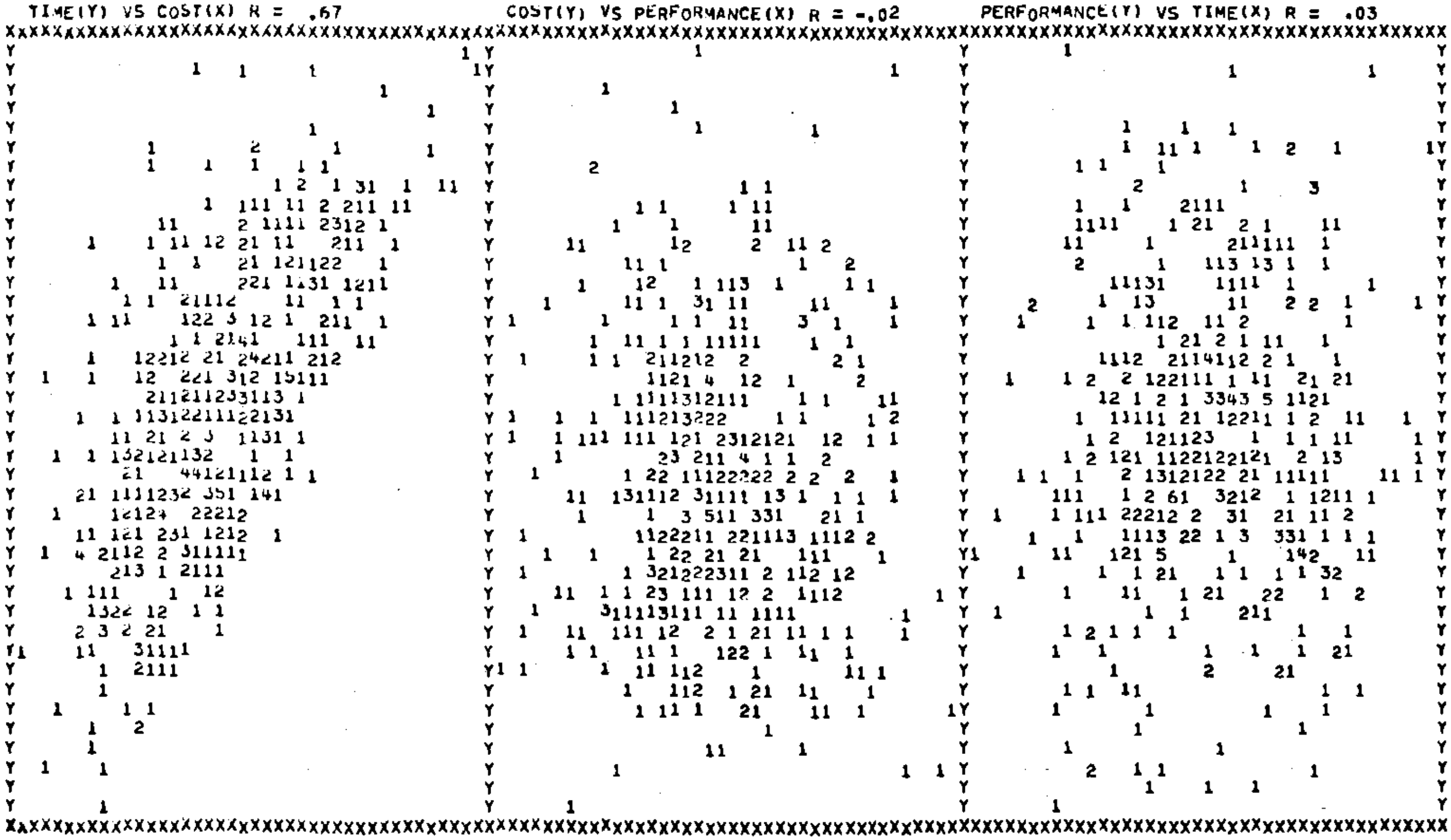
PATH PERFORMANCE FOR NODE SUCCESS
FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

Interval	RFD	CFD
4.8170 MIN		
4.8170	.000	.000
5.1972	.008	.008
5.5773	.013	.021
5.9574	.006	.027
6.3376	.013	.040
6.7177	.021	.061
7.0979	.021	.082
7.4780	.027	.109
7.8582	.046	.156
8.2383	.061	.217
8.6184	.086	.303
8.9986	.084	.387
9.3787	.082	.469
9.7589	.078	.547
10.1390	.088	.636
10.5191	.069	.705
10.8993	.057	.762
11.2794	.034	.796
11.6596	.042	.838
12.0397	.046	.884
12.4198	.040	.924
12.8000	.025	.949
13.1801	.017	.966
13.5603	.021	.987
13.9404	.006	.994
14.3205	.000	.994
14.7007	.006	1.000
14.7007 MAX	.000	.000

NO. OBS. = 475 MEAN = 9.6169 STD ERROR = 1.8730 COEF OF VARIATION = .19 KURTOSIS (BETA 2) = 2.79
MODE = 9.8946 PEARSONIAN SKEW = .15

CORRELATIONS AND X-Y PLOTS FOR PRECEEDING NODE
(* MEANS PLOTTING 10 OR MORE POINTS PER UNIT CELL)

TIME(Y) VS COST(X) R = .67 COST(Y) VS PERFORMANCE(X) R = -.02 PERFORMANCE(Y) VS TIME(X) R = .03



NOTE---PATH COST WAS USED IN THIS PLOT

```
          RFD   .05  .10  .15  .20  .25                      CFD  .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
   1.6234 I----I----I----I----I----I MIN              1.6234 I----I----I----I----I----I----I----I----I----I----I MIN
          I                           .000                   I                                                   .000
   1.6234 I                                           1.6234 I
          I****                       .040                   I**                                                 .040
   1.8298 I                                           1.8298 I
          I****                       .040                   I****                                               .080
   2.0362 I                                           2.0362 I
          I                           .000                   I****                                               .080
   2.2427 I                                           2.2427 I
          I********                   .080                   I********                                           .160
   2.4491 I                                           2.4491 I
          I****                       .040                   I**********                                         .200
   2.6555 I                                           2.6555 I
          I                           .000                   I**********                                         .200
   2.8619 I                                           2.8619 I
          I********                   .080                   I**************                                     .280
   3.0683 I                                           3.0683 I
          I********                   .080                   I******************                                 .360
   3.2747 I                                           3.2747 I
          I********************       .200                   I****************************                       .560
   3.4811 I                                           3.4811 I
          I                           .000                   I****************************                       .560
   3.6875 I                                           3.6875 I
          I********                   .080                   I********************************                   .640
   3.8940 I                                           3.8940 I
          I                           .000                   I********************************                   .640
   4.1004 I                                           4.1004 I
          I                           .000                   I********************************                   .640
   4.3068 I                                           4.3068 I
          I********                   .080                   I************************************               .720
   4.5132 I                                           4.5132 I
          I********                   .080                   I****************************************           .800
   4.7196 I                                           4.7196 I
          I********                   .080                   I********************************************       .880
   4.9260 I                                           4.9260 I
          I                           .000                   I********************************************       .880
   5.1324 I                                           5.1324 I
          I****                       .040                   I**********************************************     .920
   5.3388 I                                           5.3388 I
          I                           .000                   I**********************************************     .920
   5.5453 I                                           5.5453 I
          I                           .000                   I**********************************************     .920
   5.7517 I                                           5.7517 I
          I****                       .040                   I************************************************   .960
   5.9581 I                                           5.9581 I
          I                           .000                   I************************************************   .960
   6.1645 I                                           6.1645 I
          I                           .000                   I************************************************   .960
   6.3709 I                                           6.3709 I
          I                           .000                   I************************************************   .960
   6.5773 I                                           6.5773 I
          I                           .000                   I************************************************   .960
   6.7837 I                                           6.7837 I
          I****                       .040                   I**************************************************1.000
   6.9901 I                                           6.9901 I
          I                           .000                   I                                                   .000
   6.9901 I                           MAX             6.9901 I                                                   MAX
NO. OBS. =   25  MEAN =            3.7451  STD ERROR =          1.2533  COEF OF VARIATION =   .33  KURTOSIS (BETA 2) =  3.02
                 MODE =            3.3521  PEARSONIAN SKEW =   .31
```

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA
NETWORK TIME FOR NODE FAILP

PATH COST FOR NODE FAILP
FALLON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

```
          RFD  .05  .10  .15  .20  .25                         CFD  .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
31.5764 I----I----I----I----I----I MIN                 31.5764 I----I----I----I----I----I----I----I----I----I----I MIN
        I                          .000                        I                                                   .000
31.5764 I                                              31.5764 I
        I****                      .040                        I**                                                 .040
34.1251 I                                              34.1251 I
        I****                      .040                        I****                                               .080
36.6739 I                                              36.6739 I
        I********                  .080                        I********                                           .160
39.2226 I                                              39.2226 I
        I****                      .040                        I**********                                         .200
41.7714 I                                              41.7714 I
        I****                      .040                        I************                                       .240
44.3201 I                                              44.3201 I
        I****                      .040                        I**************                                     .280
46.8689 I                                              46.8689 I
        I************              .120                        I********************                               .400
49.4176 I                                              49.4176 I
        I********                  .080                        I************************                           .480
51.9664 I                                              51.9664 I
        I************              .120                        I******************************                     .600
54.5151 I                                              54.5151 I
        I****                      .040                        I********************************                   .640
57.0639 I                                              57.0639 I
        I                          .000                        I********************************                   .640
59.6126 I                                              59.6126 I
        I****                      .040                        I**********************************                 .680
62.1614 I                                              62.1614 I
        I                          .000                        I**********************************                 .680
64.7101 I                                              64.7101 I
        I****                      .040                        I************************************               .720
67.2589 I                                              67.2589 I
        I                          .000                        I************************************               .720
69.8076 I                                              69.8076 I
        I********                  .080                        I****************************************           .800
72.3564 I                                              72.3564 I
        I****                      .040                        I******************************************         .840
74.9051 I                                              74.9051 I
        I                          .000                        I******************************************         .840
77.4539 I                                              77.4539 I
        I****                      .040                        I********************************************       .880
80.0026 I                                              80.0026 I
        I                          .000                        I********************************************       .880
82.5514 I                                              82.5514 I
        I                          .000                        I********************************************       .880
85.1001 I                                              85.1001 I
        I                          .000                        I********************************************       .880
87.6489 I                                              87.6489 I
        I****                      .040                        I**********************************************     .920
90.1976 I                                              90.1976 I
        I                          .000                        I**********************************************     .920
92.7464 I                                              92.7464 I
        I                          .000                        I**********************************************     .920
95.2951 I                                              95.2951 I
        I********                  .080                        I**************************************************1.000
97.8439 I                                              97.8439 I
        I                          .000                        I                                                   .000
97.8439 I                          MAX                 97.8439 I                                                   MAX
NO. OBS. =   25  MEAN =          57.6257  STD ERROR =          18.5959  COEF OF VARIATION =   .32  KURTOSIS (BETA 2) =  2.63
A MULTIMODAL DISTRIBUTION
```

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

OVERALL COST FOR NODE FAILP

```
         RFD   .05  .10  .15  .20  .25                      CFD   .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
 31.5764 I----I----I----I----I----I MIN            31.5764 I----I----I----I----I----I----I----I----I----I----I MIN
         I                          .000                   I                                                   .000
 31.5764 I                                         31.5764 I
         I****                      .040                   I**                                                 .040
 36.8567 I                                         36.8567 I
         I****                      .040                   I****                                               .080
 42.1371 I                                         42.1371 I
         I                          .000                   I****                                               .080
 47.4174 I                                         47.4174 I
         I****                      .040                   I******                                             .120
 52.6978 I                                         52.6978 I
         I********                  .080                   I**********                                         .200
 57.9781 I                                         57.9781 I
         I********                  .080                   I**************                                     .280
 63.2585 I                                         63.2585 I
         I************              .120                   I********************                               .400
 68.5389 I                                         68.5389 I
         I********************      .200                   I******************************                     .600
 73.8192 I                                         73.8192 I
         I********                  .080                   I**********************************                 .680
 79.0996 I                                         79.0996 I
         I                          .000                   I**********************************                 .680
 84.3799 I                                         84.3799 I
         I********                  .080                   I**************************************             .760
 89.6603 I                                         89.6603 I
         I****                      .040                   I****************************************           .800
 94.9406 I                                         94.9406 I
         I                          .000                   I****************************************           .800
100.2210 I                                        100.2210 I
         I****                      .040                   I******************************************         .840
105.5013 I                                        105.5013 I
         I                          .000                   I******************************************         .840
110.7817 I                                        110.7817 I
         I                          .000                   I******************************************         .840
116.0621 I                                        116.0621 I
         I                          .000                   I******************************************         .840
121.3424 I                                        121.3424 I
         I****                      .040                   I********************************************       .880
126.6228 I                                        126.6228 I
         I                          .000                   I********************************************       .880
131.9031 I                                        131.9031 I
         I                          .000                   I********************************************       .880
137.1835 I                                        137.1835 I
         I                          .000                   I********************************************       .880
142.4638 I                                        142.4638 I
         I********                  .080                   I************************************************   .960
147.7442 I                                        147.7442 I
         I                          .000                   I************************************************   .960
153.0245 I                                        153.0245 I
         I                          .000                   I************************************************   .960
158.3049 I                                        158.3049 I
         I                          .000                   I************************************************   .960
163.5853 I                                        163.5853 I
         I****                      .040                   I**************************************************1.000
168.8656 I                                        168.8656 I
         I                          .000                   I                                                   .000
168.8656 I                          MAX           168.8656 I                                                   MAX
NO. OBS. =   25  MEAN =          80.3414  STD ERROR =          33.6641  COEF OF VARIATION =   .42  KURTOSIS (BETA 2) =  3.57
                 MODE =          70.6510  PEARSONIAN SKEW =   .29
```

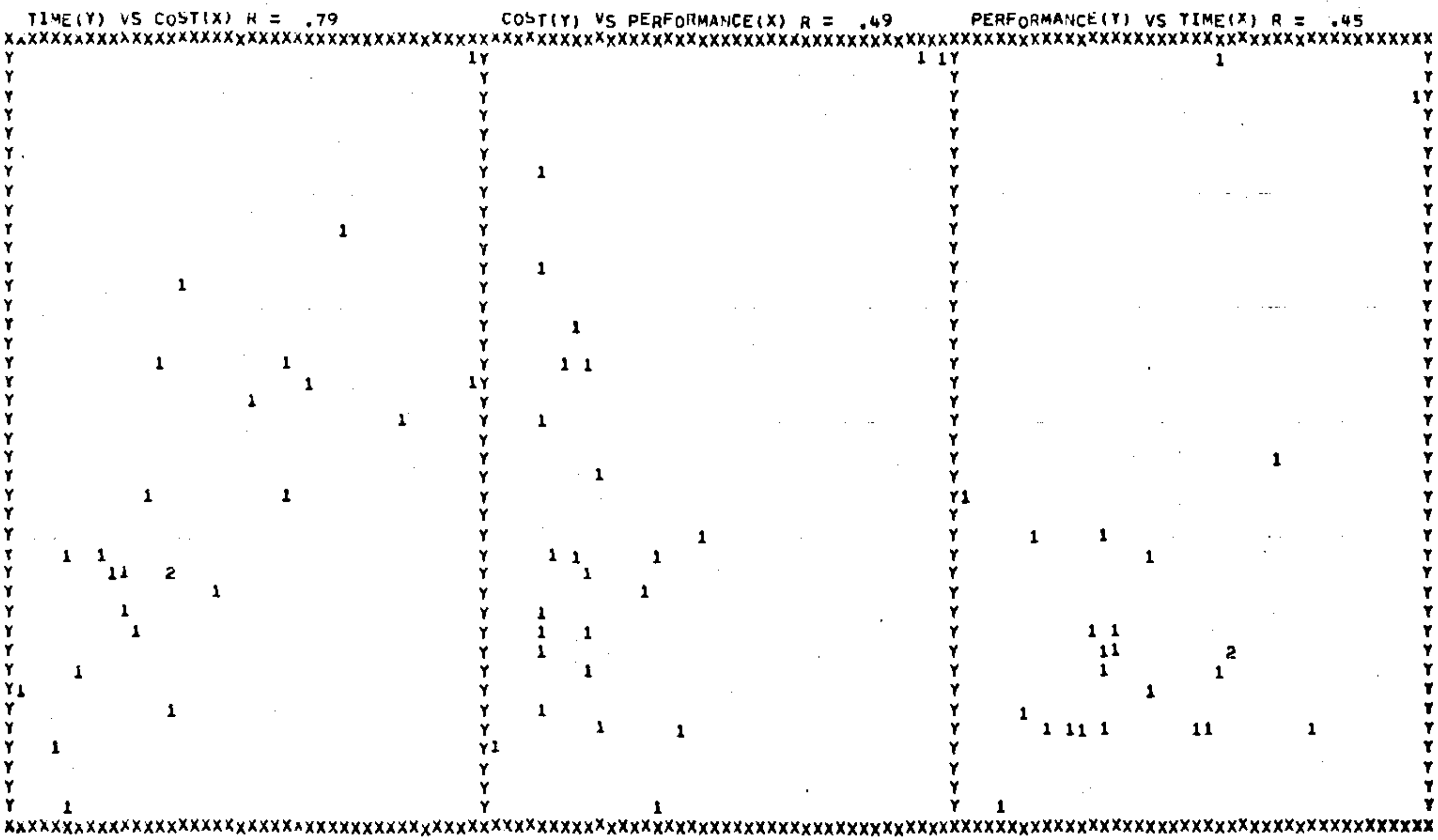
PATH PERFORMANCE FOR NODE FAILP

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

	RFD (.05 .10 .15 .20 .25)	CFD (.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0)
-1.7449	MIN	MIN
	.000	.000
-1.7449		
	.040	.040
-1.1546		
	.000	.040
-.5643		
	.280	.320
.0260		
	.040	.360
.6164		
	.120	.480
1.2067		
	.160	.640
1.7970		
	.080	.720
2.3873		
	.000	.720
2.9776		
	.040	.760
3.5679		
	.080	.840
4.1582		
	.040	.880
4.7485		
	.000	.880
5.3388		
	.040	.920
5.9291		
	.000	.920
6.5194		
	.000	.920
7.1097		
	.000	.920
7.7000		
	.000	.920
8.2903		
	.000	.920
8.8807		
	.000	.920
9.4710		
	.000	.920
10.0613		
	.000	.920
10.6516		
	.000	.920
11.2419		
	.000	.920
11.8322		
	.000	.920
12.4225		
	.040	.960
13.0128		
	.040	1.000
13.6031		
	.000	.000
13.6031	MAX	MAX

NO. OBS. = 25 MEAN = 2.3058 STD ERROR = 3.6740 COEF OF VARIATION = 1.59 KURTOSIS (BETA 2) = 6.54
MODE = -.2464 PEARSONIAN SKEW = .69

CORRELATIONS AND X-Y PLOTS FOR PRECEEDING NODE
(* MEANS PLOTTING 10 OR MORE POINTS PER UNIT CELL)



NOTE---PATH COST WAS USED IN THIS PLOT

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

NETWORK TIME FOR THE COMPOSITE TERMINAL NODE

RFD .05 .10 .15 .20 .25 — CFD .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Cell boundary	RFD	CFD
1.6234	MIN	MIN
	.000	.000
1.6234		
	.002	.002
1.9712		
	.002	.004
2.3191		
	.006	.010
2.6669		
	.004	.014
3.0147		
	.010	.024
3.3625		
	.004	.028
3.7104		
	.004	.032
4.0582		
	.000	.032
4.4060		
	.008	.040
4.7538		
	.004	.044
5.1017		
	.002	.046
5.4495		
	.000	.046
5.7973		
	.008	.054
6.1451		
	.014	.068
6.4929		
	.024	.092
6.8408		
	.062	.154
7.1886		
	.088	.242
7.5364		
	.128	.370
7.8842		
	.110	.480
8.2321		
	.130	.610
8.5799		
	.124	.734
8.9277		
	.098	.832
9.2755		
	.084	.916
9.6234		
	.056	.972
9.9712		
	.014	.986
10.3190		
	.014	1.000
10.6668		
	.000	.000
10.6668	MAX	MAX

NO. OBS. = 500 MEAN = 8.1167 STD ERROR = 1.3778 COEF OF VARIATION = .17 KURTOSIS (BETA 2) = 7.85
MODE = 8.4996 PEARSONIAN SKEW = .28

PATH COST FOR THE COMPOSITE TERMINAL NODE
FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

```
          RFD   .05  .10  .15  .20  .25
 31.5764 I----I----I----I----I----I MIN
         I                          .000
 31.5764 I
         I                          .002
 35.7469 I
         I                          .008
 39.9174 I
         I                          .002
 44.0880 I
         I                          .006
 48.2585 I
         I                          .006
 52.4291 I
         I                          .008
 56.5996 I
         I                          .000
 60.7701 I
         I                          .002
 64.9407 I
         I                          .002
 69.1112 I
         I                          .004
 73.2817 I
         I                          .002
 77.4523 I
         I                          .004
 81.6228 I
         I                          .006
 85.7934 I
         I***                       .036
 89.9639 I
         I*******                   .074
 94.1344 I
         I************              .124
 98.3050 I
         I*************             .132
102.4755 I
         I*************             .134
106.6461 I
         I*************             .136
110.8166 I
         I**********                .102
114.9871 I
         I*******                   .074
119.1577 I
         I******                    .068
123.3282 I
         I***                       .040
127.4988 I
         I*                         .016
131.6693 I
         I                          .006
135.8398 I
         I                          .006
140.0104 I
         I                          .000
140.0104 I                          MAX
```

```
          CFD   .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
 31.5764 I----I----I----I----I----I----I----I----I----I----I MIN
         I                                                   .000
 31.5764 I
         I                                                   .002
 35.7469 I
         I                                                   .010
 39.9174 I
         I*                                                  .012
 44.0880 I
         I*                                                  .018
 48.2585 I
         I*                                                  .024
 52.4291 I
         I**                                                 .032
 56.5996 I
         I**                                                 .032
 60.7701 I
         I**                                                 .034
 64.9407 I
         I**                                                 .036
 69.1112 I
         I**                                                 .040
 73.2817 I
         I**                                                 .042
 77.4523 I
         I**                                                 .046
 81.6228 I
         I***                                                .052
 85.7934 I
         I****                                               .088
 89.9639 I
         I********                                           .162
 94.1344 I
         I**************                                     .286
 98.3050 I
         I*********************                              .418
102.4755 I
         I****************************                       .552
106.6461 I
         I**********************************                 .688
110.8166 I
         I****************************************           .790
114.9871 I
         I*******************************************        .864
119.1577 I
         I***********************************************    .932
123.3282 I
         I*************************************************  .972
127.4988 I
         I*************************************************  .988
131.6693 I
         I************************************************** .994
135.8398 I
         I**************************************************1.000
140.0104 I
         I                                                   .000
140.0104 I                                                   MAX
```

NO. OBS. = 500 MEAN = 104.0501 STD ERROR = 15.4694 COEF OF VARIATION = .15 KURTOSIS (BETA 2) = 8.03
MODE = 106.8778 PEARSONIAN SKEW = .18

OVERALL COST FOR THE COMPOSITE TERMINAL NODE

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

```
         RFD   .05  .10  .15  .20  .25                       CFD  .1   .2   .3   .4   .5   .6   .7   .8   .9  1.0
 31.5764 I----I----I----I----I----I MIN               31.5764 I----I----I----I----I----I----I----I----I----I----I MIN
         I                          .000                      I                                                   .000
 31.5764 I                                            31.5764 I
         I                          .004                      I                                                   .004
 38.8787 I                                            38.8787 I
         I                          .000                      I                                                   .004
 46.1810 I                                            46.1810 I
         I                          .002                      I                                                   .006
 53.4833 I                                            53.4833 I
         I                          .006                      I*                                                  .012
 60.7856 I                                            60.7856 I
         I                          .008                      I*                                                  .020
 68.0879 I                                            68.0879 I
         I                          .010                      I*                                                  .030
 75.3903 I                                            75.3903 I
         I                          .004                      I**                                                 .034
 82.6926 I                                            82.6926 I
         I                          .004                      I**                                                 .038
 89.9949 I                                            89.9949 I
         I                          .002                      I**                                                 .040
 97.2972 I                                            97.2972 I
         I                          .000                      I**                                                 .040
104.5995 I                                           104.5995 I
         I                          .002                      I**                                                 .042
111.9018 I                                           111.9018 I
         I                          .000                      I**                                                 .042
119.2042 I                                           119.2042 I
         I                          .002                      I**                                                 .044
126.5065 I                                           126.5065 I
         I                          .000                      I**                                                 .044
133.8088 I                                           133.8088 I
         I                          .008                      I***                                                .052
141.1111 I                                           141.1111 I
         I*******                   .072                      I******                                             .124
148.4134 I                                           148.4134 I
         I*******                   .078                      I**********                                         .202
155.7157 I                                           155.7157 I
         I****************          .156                      I******************                                 .358
163.0181 I                                           163.0181 I
         I*****************         .162                      I**************************                         .520
170.3204 I                                           170.3204 I
         I****************          .160                      I**********************************                 .680
177.6227 I                                           177.6227 I
         I************              .120                      I****************************************           .800
184.9250 I                                           184.9250 I
         I**********                .098                      I*********************************************      .898
192.2273 I                                           192.2273 I
         I******                    .056                      I************************************************   .964
199.5296 I                                           199.5296 I
         I**                        .024                      I*************************************************  .988
206.8320 I                                           206.8320 I
         I                          .008                      I************************************************** .996
214.1343 I                                           214.1343 I
         I                          .004                      I**************************************************1.000
221.4366 I                                           221.4366 I
         I                          .000                      I                                                   .000
221.4366 I                          MAX              221.4366 I                                                   MAX
NO. OBS. =  500  MEAN =          166.7562  STD ERROR =         26.1360  COEF OF VARIATION =   .16  KURTOSIS (BETA 2) = 10.58
                 MODE =          168.4948  PEARSONIAN SKEW =    .07
```

FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA

PATH PERFORMANCE FOR THE COMPOSITE TERMINAL NODE

RFD scale: .05 .10 .15 .20 .25 — CFD scale: .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

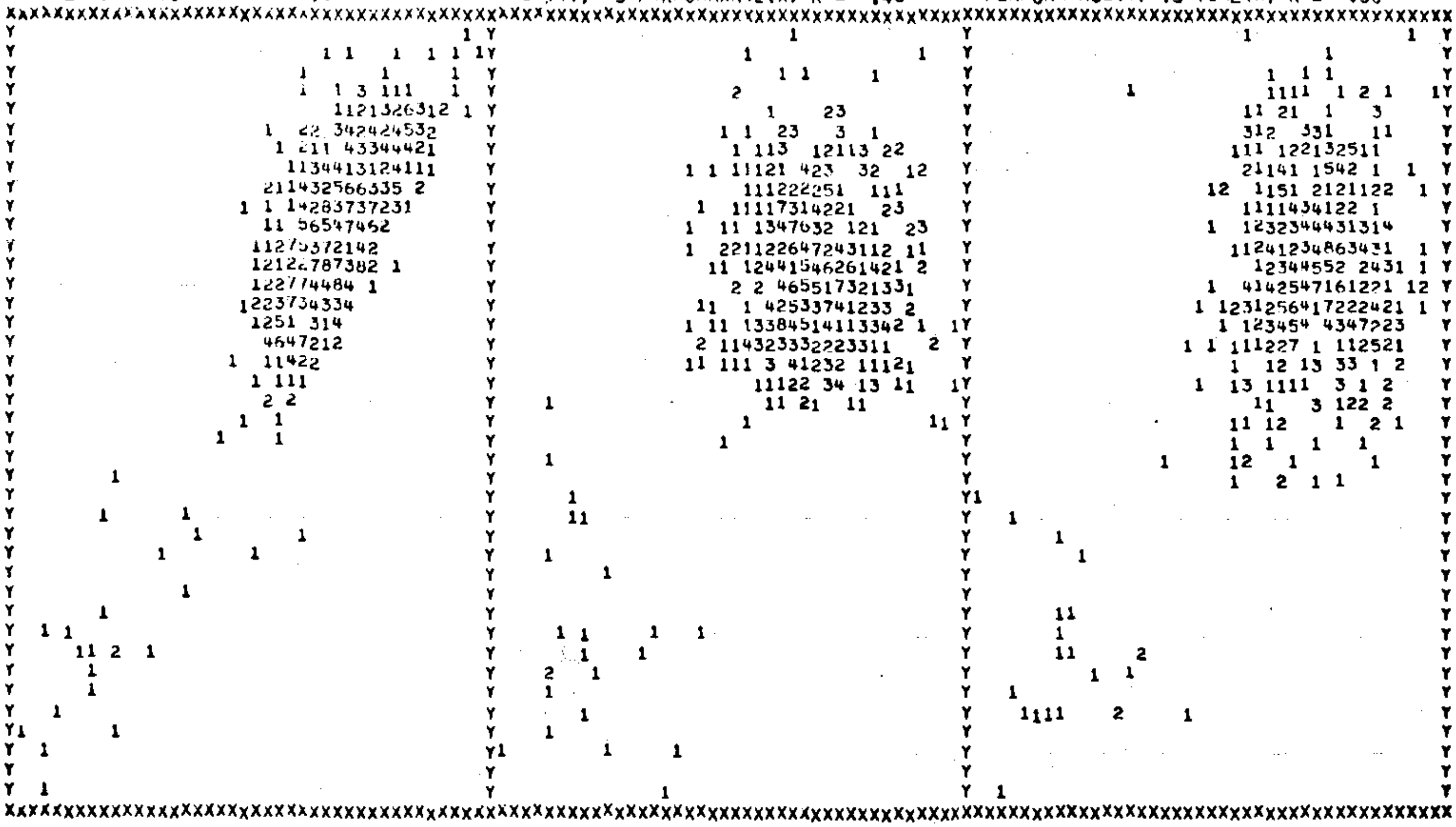
Interval boundary	RFD	CFD
-1.7449 (MIN)		
	.000	.000
-1.7449		
	.002	.002
-1.1124		
	.000	.002
-.4798		
	.014	.016
.1527		
	.004	.020
.7852		
	.010	.030
1.4177		
	.006	.036
2.0503		
	.000	.036
2.6828		
	.000	.036
3.3153		
	.004	.040
3.9478		
	.004	.044
4.5803		
	.010	.054
5.2129		
	.018	.072
5.8454		
	.020	.092
6.4779		
	.032	.124
7.1104		
	.056	.180
7.7429		
	.102	.282
8.3755		
	.140	.422
9.0080		
	.126	.548
9.6405		
	.124	.672
10.2730		
	.098	.770
10.9056		
	.062	.832
11.5381		
	.066	.898
12.1706		
	.052	.950
12.8031		
	.032	.982
13.4356		
	.012	.994
14.0682		
	.006	1.000
14.7007		
	.000	.000
14.7007 (MAX)		

NO. OBS. = 500 MEAN = 9.2513 STD ERROR = 2.5546 COEF OF VARIATION = .28 KURTOSIS (BETA 2) = 6.15

MODE = 8.8377 PEARSONIAN SKEW = .16

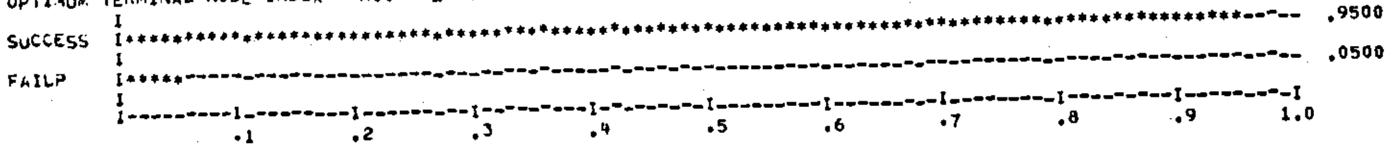
CORRELATIONS AND X-Y PLOTS FOR PRECEEDING NODE
(* MEANS PLOTTING 10 OR MORE POINTS PER UNIT CELL)

TIME(Y) VS COST(X) R = .84 COST(Y) VS PERFORMANCE(X) R = .46 PERFORMANCE(Y) VS TIME(X) R = .50

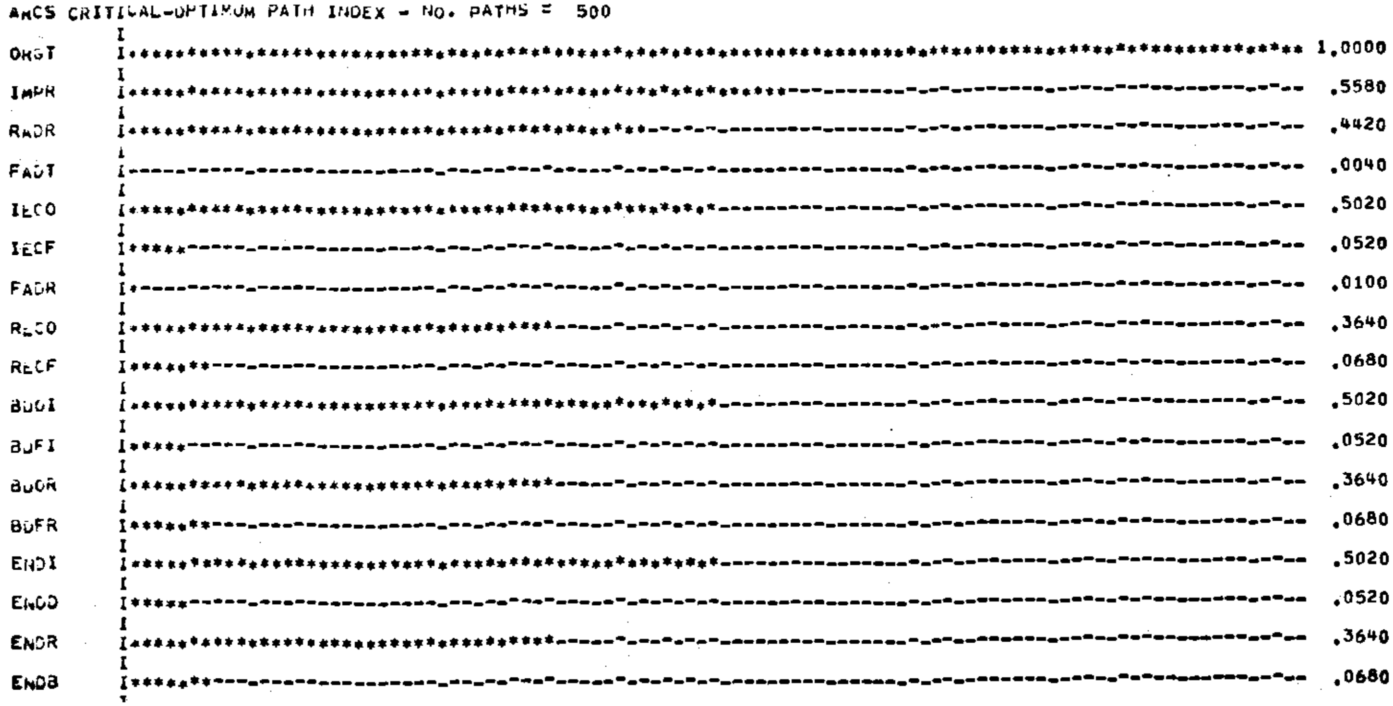


NOTE---PATH COST WAS USED IN THIS PLOT

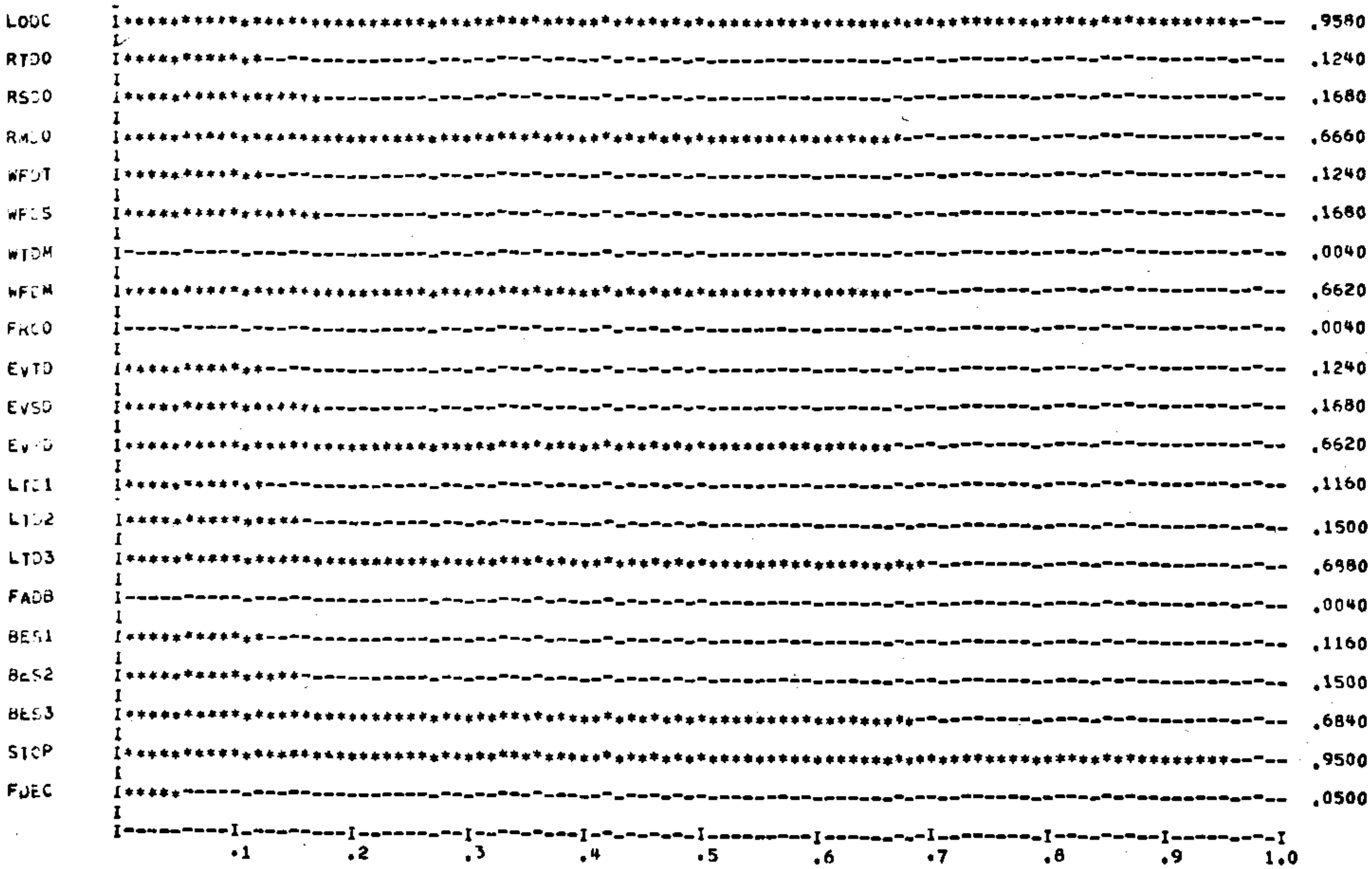
OPTIMUM TERMINAL NODE INDEX - NO. ITERATIONS = 500



ARCS CRITICAL-OPTIMUM PATH INDEX - NO. PATHS = 500



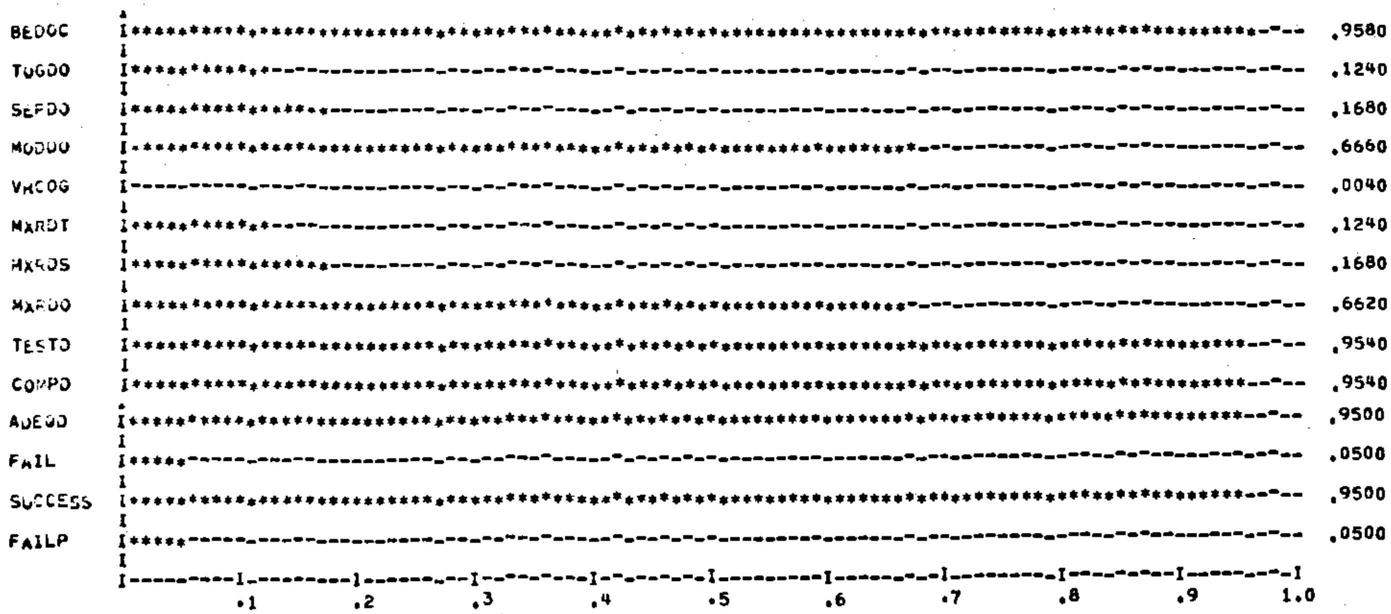
LAST	.3020
MANT	.6840
FALT	.0020
LTHA	.2760
LTMA	.0240
FAMR	.0060
MTHA	.6440
MTMA	.0340
TSPL	.2760
TSML	.0240
TSPM	.6440
TSMM	.0340
HVLA	.1460
LVLA	.1540
HVMA	.1040
LVMA	.5740
BTLA	.1460
BTLB	.1540
BTMA	.1040
BTMB	.5740
MPE1	.1460
MPE2	.1540
MPE3	.1020
MPE4	.5660
FATK	.0100
FSYS	.0100



RANDOM NUMBER SEED AT THE CLOSE OF THE SIMULATION-------------------------------- 32753515096

NODES CRITICAL-OPTIMUM PATH INDEX - NO. PATHS = 500

NODES	INDEX
START	1,0000
BEGID	1,0000
IMPSC	,5580
RADSC	,4420
MIIDI	,5540
MIIDR	,4320
BESTI	,9860
BEGTK	,9860
LASYS	,3020
MTSYS	,6840
MITKL	,3000
MITKM	,6780
LAWTR	,3000
MAWTR	,6780
MILTV	,3000
MIMTV	,6780
BESTK	,9780
TERMT	,9680


BEDOC .9580
TUGDO .1240
SEFDO .1680
MODUO .6660
VHCOG .0040
MXRDT .1240
MXRDS .1680
MXRDO .6620
TESTO .9540
COMPO .9540
ADEQD .9500
FAIL .0500
SUCCESS .9500
FAILP .0500
.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

```
FALCON - RUN NO 1 - OUTPUT OPTION 0 - NORMAL DATA
RUN IDENTIFICATION CARD OPTION------------------------------------------        1
TYPE OF RUN OPTION------------------------------------------------------        1
TYPE OF OUTPUT OPTION---------------------------------------------------        0
COSTING AND PRUNNING OPTION---------------------------------------------        1
INITIAL SEED------------------------------------------------------------  32753515096
NUMBER OF ITERATIONS----------------------------------------------------      500
YEARLY INTEREST RATE USED FOR PRESENT VALUE DISCOUNTING-----------------      .00
TIME FACTOR WHICH CONVERTS PROGRAM TIME TO A YEARLY BASIS---------------      .00
                                        TIME      COST  PERFORMANCE
TERMINAL NODE SELECTION WEIGHTS          .00       .00      1.00
CRITICAL - OPTIMUM PATH WEIGHTS          .00       .00      1.00
INITIAL PROBLEM VALUES                   .00       .00       .00

ENDARC
FAILP    3  1  -1
ENDNODE
```

OPTIMAL PATH HAS BEEN REQUESTED. THIS REQUIRES AN ADDITIONAL AMOUNT OF COMPUTER TIME.

```
                        NETWORK TIME FOR NODE SUCCESS
NO. OBS. =  473  MIN =          6.1624  AVE =          8.3057  MAX =        11.0210
                        PATH COST FOR NODE SUCCESS
NO. OBS. =  473  MIN =         77.5081  AVE =        106.0141  MAX =       140.9018
                        OVERALL COST FOR NODE SUCCESS
NO. OBS. =  473  MIN =        135.9667  AVE =        170.8038  MAX =       216.7230
                        PATH PERFORMANCE FOR NODE SUCCESS
NO. OBS. =  473  MIN =          3.7250  AVE =          9.7333  MAX =        15.9342
                        NETWORK TIME FOR NODE FAILP
NO. OBS. =   27  MIN =          1.9651  AVE =          3.6943  MAX =         5.3468
                        PATH COST FOR NODE FAILP
NO. OBS. =   27  MIN =         32.5021  AVE =         54.4349  MAX =        89.7366
                        OVERALL COST FOR NODE FAILP
NO. OBS. =   27  MIN =         38.5049  AVE =         74.5297  MAX =       146.1321
                        PATH PERFORMANCE FOR NODE FAILP
NO. OBS. =   27  MIN =         -5.5744  AVE =           .8582  MAX =         5.9578
                        NETWORK TIME FOR THE COMPOSITE TERMINAL NODE
NO. OBS. =  500  MIN =          1.9651  AVE =          8.0567  MAX =        11.0210
                        PATH COST FOR THE COMPOSITE TERMINAL NODE
NO. OBS. =  500  MIN =         32.5021  AVE =        103.2288  MAX =       140.9018
                        OVERALL COST FOR THE COMPOSITE TERMINAL NODE
NO. OBS. =  500  MIN =         38.5049  AVE =        165.6050  MAX =       216.7230
                        PATH PERFORMANCE FOR THE COMPOSITE TERMINAL NODE
NO. OBS. =  500  MIN =         -5.5744  AVE =          9.2541  MAX =        15.9342
```

APPENDIX III

VERT PROGRAM CHANGES

Listed below are program changes for VERT subroutines DOARC,RANDOM and GAM. These changes were necessary to convert this program to the smaller-bit UNIVAC 1108 computer.

```
      SUBROUTINE GAM
      (COMMON BLOCKS AS LISTED)
      TIMESM = 0.0
      DO 7477 I = 1,ISAVE
      CALL RANDOM
7477  TIMESM = TIMESM + ALOG(UNFORM)
      RETURN

      SUBROUTINE RANDOM
      (COMMON BLOCKS AS LISTED)
      ISEED = ISEED*3125
      IF(ISEED) 5377,5388,5388
5377  ISEED = ISEED + 34359738367 + 1
5388  UNFORM = ISEED
      UNFORM = UNFORM*2.0**(-35)
      RETURN
      END

      SUBROUTINE DOARC
      UNFORM = -(TIMESM)/ASTORE(I3)                 GLM27330
```

```
UNFORM = -(TIMESM)/0.5 + PROB1          GLM27510
PROB1 + -(TIMESM)
PROB2 = -(TIMESM)
```

APPENDIX IV

FALCON RUN DATA

The following pages contain computer listings of the data in VERT input format which generated the runs in the body of the thesis. The run identification can be made by the alpha-numeric card listed second in the data listing. The reader is referred to the VERT instructions by Mr Moeler for an explanation of individual data elements.

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1 31              96581  15                   1.0        1.0
FALCON - RUN NO 1 - OUTPUT OPTION 3 - NORMAL DATA
ORGT     START    BEGID    1.0  OGANIZE TEST DIRECTORATE
ORGT     DTIME 1     2.0           .5           1.5
ORGT     DCOST 1     3.0           10.0         19.0         15.0
IMPR     BEGID    IMPSC    1.0  IMPROVED RADAR DETECTION
IMPR     DTIME 1     4.0           .5           1.5          1.0         .15
IMPR     RCOST 1 1STIMPR      K 10.0     K 1.0
IMPR     DPERF 1     4.0           .5           35.0         20.0        8.0
RADR     BEGID    RADSC    1.0  BASIC RADAR DETECTION
RADR     DTIME 1     4.0           .5           1.5          1.0         .15
RADR     RCOST 1 1STRADR      K 10.0     K 1.0
RADR     DPERF 1     4.0           .3           30.0         18.0        8.0
FADT     IMPSC    FAIL     1.0  FAIL TO DETECT GE 5 K IMPROVE
IECO     IMPSC    MIIDI    .90  ECM ON IMPROVED RADAR
IECO     FILT1 1                                                         5.0        50.0
IECO     RCOST 1 1SCIMPR      K .5       K 1.0
IECO     DPERF 1     4.0         -10.0         -.1          -5.0         3.0
IECF     IMPSC    MIIDI    .95  ECM OFF IMPROVED RADAR
IECF     FILT1 1                                                         5.0        50.
FADR     RADSC    FAIL     1.0  FAIL TO DETECT GE 5 K REGULAR
RECO     RADSC    MIIDR    .90   ECM ON REGULAR
RECO     FILT1 1                                                         5.0        50.
RECO     RCOST 1 1SCRADR      K .5       K 1.0
RECO     DPERF 1     4.0         -11.0         -1.0         -5.0         3.0
RECF     RADSC    MIIDR    .95  ECM OFF REGULAR
RECF     FILT1 1                                                         5.0        50.
FATI     MIIDI    FAIL     1.0  FAIL COMPARISON RELIABILITY IMPROVED
BDOI     MIIDI    BESTI    1.0  SUCCESS ECM ON IMPROVED
BDFI     MIIDI    BESTI    1.0  SUCCESS ECM OFF IMPROVED
FATR     MIIDR    FAIL     1.0  FAIL COMPARISON RELIABILITY REGULAR
BDOR     MIIDR    BESTI    1.0  SUCCESS ECM ON REGULAR
BDFR     MIIDR    BESTI    1.0  SUCCESS ECM OFF REGULAR
FATS     BESTI    FAIL     1.0  FAIL COMPARISON DECTION
FNDI     BESTI    BEGTK    1.0  BEST VALUE IMPROVED SYSTEM
FNDD     BESTI    BEGTK    1.0  BEST VALUE IMPROVED ECM OFF
FNDR     BESTI    BEGTK    1.0  BEST VALUE REGULAR
FNDP     BESTI    BEGTK    1.0  BEST VALUE REGULAR ECM OFF
LAST     BEGTK    LASYS    1.0  LASER TRACK FIRE SYSTEM
LAST     DTIME 1     4.0           .5           3.0          1.2         .9
LAST     RCOST 1 1STLAST      K 10.0     K 1.0
LAST     DPERF 1     4.0          -2.2         -.1          -1.0         .4
MANT     BEGTK    MTSYS    1.0  MANUAL TRACK FIRE SYSTEM
MANT     DTIME 1     4.0           .5           3.0          1.2         .9
MANT     RCOST 1 1STMANT      K 10.0     K 1.0
MANT     DPERF 1     4.0          -4.2         -.3          -1.1         .9
FALT     LASYS    FAIL     1.0  FAIL LASER TRACK/FIRE GT 3 K
LTHA     LASYS    MITKL    .95  HIGH ALTITUDE EFFECT LASER
LTHA     FILT1 1                                                         3.0        50.
LTHA     DPERF 1     4.0          -.9          -.5          -.75         .1
LTMA     LASYS    MITKL    .90  MEDIUM ALTITUDE EFFECT LASER
LTMA     FILT1 1                                                         3.0        50.
LTMA     DPERF 1     4.0          -.9           .5           0.0         .25
LTMA     RCOST 1 1SCLAST      K .2       K 1.0
FAMP     MISYS    FAIL     1.0  FAIL MANUAL TRACK/FIRE GT 3 K
MTHA     MISYS    MITKM    .95  HIGH ALTITUDE EFFECT MANUAL
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MTHA     FILT1 1                                                   3.0       50.
MTHA     OPERF 1     4.0      -1.5       -.8       -1.0       .1
MTMA     MISYS   MITKM   .90  MEDIUM ALTITUDE EFFECT MANUAL
MTMA     FILT1 1                                                   3.0       50.
MTMA     OPERF 1     4.0      -1.2        .8        0.0       .25
MTMA     RCOST 1 1SCMANT    K .2      K 1.0
FALI     MITKL   FAIL    1.0  FAIL LASER COMPARISON ALTITUDE
TSPL     MITKL   LAWTR   1.0  SUCCESS LASER HIGH ALTITUDE
TSML     MITKL   LAWTR   1.0  SUCCESS LASER MEDIUM ALTITUDE
FAMI     MITKM   FAIL    1.0  FAIL MANUAL COMPARISON ALTITUDE
TSPM     MITKM   MAWTR   1.0  SUCCESS MANUAL HIGH ALTITUDE
TSMM     MITKM   MAWTR   1.0  SUCCESS MANUAL MED ALTITUDE
HVLA     LAWTR   MILTV   .95  HIGH VISIBILITY LASER ECM OFF
HVLA     OPERF 1     4.0      -5.0      -1.0       -3.0       .75
LVLA     LAWTR   MILTV   .90  LOW VISIBILITY LASER ECM ON
LVLA     OPERF 1     4.0      -9.0      -2.0       -4.0       1.5
LVLA     RCOST 1 1SCLAST    K .1      K 1.0
HVMA     MAWTR   MIMTV   .95  HIGH VISIBILITY MANUAL TRACK
HVMA     OPERF 1     4.0      -1.0       1.0        0.0       .25
LVMA     MAWTR   MIMTV   .90  LOW VISIBILITY MANUAL
LVMA     OPERF 1     4.0      -5.0      -2.0       -3.0       .8
LVMA     RCOST 1 1SCMANT    K .1      K 1.0
FAVL     MILTV   FAIL    1.0  FAIL LASER VISIBILITY COMPARISON
BTLA     MILTV   BESTK   .95  SUCCESS HIGH VISIBILITY LASER
BTLB     MILTV   BESTK   .90  SUCCESS LOW VISIBILITY LASER
FAVM     MIMTV   FAIL    1.0  FAIL MANUAL VISIBILITY COMPARISON
BTMA     MIMTV   BESTK   .95  SUCCESS HIGH VISIBILITY MANUAL
BTMB     MIMTV   BESTK   .90  SUCCESS LOW VISIBILITY MANUAL
MPF1     BESTK   TERMT   1.0  SUCCESS LASER HIGH VISIBILITY ECM ON
MPF2     BESTK   TERMT   1.0  SUCCESS LASER LV ECM OFF
MPF3     BESTK   TERMT   1.0  SUCCESS MANUAL HIGH VISIBILITY , ALTITUDE
MPF4     BESTK   TERMT   1.0  SUCCESS MANUAL LOW VISIBILITY
FATK     BESTK   FAIL    1.0  FAIL TRACK COMPARISON
FSYS     TERMT   FAIL    1.0  FAIL TRACK/FIRE CYCLE GT 2 K
LODC     TERMT   BEDOC   1.0  BEGIN DOCTRINE TEST
LODC     FILT1 1                                                   2.0       50.
LODC     RPERF 1 1SPTERMT   K -1.0    K 1.0
LODC     DCOST 1     4.0      10.5      25.8       18.5       4.0
RTDO     BEDOC   TOGDO   1.0  RADAR TOGETHER DOCTRINE
RTDO     DTIME 1     4.0      .8         3.0        1.5       .1
RTDO     RCOST 1 1STRTDO    K 10.0    K 1.0
RTDO     OPERF 1     4.0      1.5       35.0       19.0       4.0
RSDO     BEDOC   SEPDO   1.0  RADAR SEPARATE DOCTRINE
RSDO     DTIME 1     4.0      .8         3.0        1.5       .1
RSDO     RCOST 1 1STRSDO    K 10.0    K 1.0
RSDO     OPERF 1     4.0      5.0       39.0       20.0       4.0
RMDO     BEDOC   MODDO   1.0  MODERATE DOCTRINE
RMDO     DTIME 1     4.0      .8         3.0        1.5       .1
RMDO     RCOST 1 1STRMDO    K 10.0    K 1.0
RMDO     OPERF 1     4.0      2.5       37.0       19.5       4.0
FATO     TOGDO   FAIL    1.0  FAIL TOGETHER DOCTRINE GT 5 K
WTDT     TOGDO   MXRDT   1.0  WEAPONS TIGHT TOGETHER DOCTRINE
WTDT     FILT1 1                                                   5.0       50.
WTDT     OPERF 1     4.0      -6.5      -3.5       -5.0       .8
WFDT     TOGDO   MXRDT   1.0  WEAPONS FREE TOGETHER DOCTRINE
WFDT     FILT1 1                                                   5.0       50.
WFDT     OPERF 1     4.0      -1.0       2.2        0.0       .7
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FASO     SEPDO    FAIL     1.0  FAIL SEPARATE DOCGRINE GT 5 K
WTDS     SEPDO    MXRDS    1.0  WEAPONS TIGHT SEPARATE DOCTRINE
WTDS     FILT1 1                                                   5.0        50.
WTDS     DPERF 1    4.0        -8.5        -5.0       -6.0       .8
WFDS     SEPDO    MXRDS    1.0  WEAPONS FREE SEPARATE DOCTRINE
WFDS     FILT1 1                                                   5.0        50.
WFDS     DPERF 1    4.0         0.0         3.5        1.0       .7
FAMO     MODDO    FAIL     1.0  FAIL MODERATE DOCTRINE
WTDM     MODDO    VRCOG    1.0  VISUAL RECOGNITION REQUIRED
WTDM     FILT1 1                                                   5.0        50.
WTDM     DPERF 1    4.0        -7.5        -4.0       -5.5       .8
WFDM     MODDO    MXRDO    1.0  WEAPONS FREE MODERATE DOCTRINE
WFDM     FILT1 1                                                   5.0        50.
WFDM     DPERF 1    4.0        -.5          3.0        .5        .7
FRCO     VRCOG    FAIL     1.0  FAIL VISUAL RECOG
FRCO     M      1 .1
VRCO     VRCOG    MXRDO    1.0  VISUAL RECOGNITION SUCCESSFUL
VRCO     M      1 .9
VRCO     DPERF 1    4.0        -7.5        -4.0       -5.5       .8
FAMT     MARDT    FAIL     1.0  FAIL DOCTRINE TOGT GT 2 K
FVTD     MARDT    TESTD    .95  EVALUATE DOCTRINE TOGETHER
FVTD     FILT1 1                                                   2.0        50.
FVTD     RPERF 1 1SPMXRDT   K -1.0   K 1.0    1SPMXRDT   K .5      K 1.0
FAMS     MARDS    FAIL     1.0  FAIL DOCTRINE TOGETHER GT 2 K
FVSD     MARDS    TESTD    .90  EVALUATE DOTRINE SEPARATE
FVSD     FILT1 1                                                   2.0        50.
FVSD     RPERF 1 1SPMXRDS   K -1.0   K 1.0    1SPMXRDS   K.5       K 1.0
FAMM     MARDO    FAIL     1.0  FAIL MODERATE DOCTRINE GT 2 K
FVMD     MARDO    TESTD    .95  EVALUATE MODERATE DOCTRINE
FVMD     FILT1 1                                                   2.0        50.
FVMD     RPERF 1 1SPMXRDO   K -1.0   K 1.0    1SPMXRDO   K .5      K 1.0
FAPC     TESTD    FAIL     1.0  FAIL DOCTRINE COMPARISON SMALL TEST
LTD1     TESTD    COMPD    .95  LARGE TEST TOGETHER DOCTRINE
LTD1     DPERF 1    4.0        -2.0        -.5        -1.0       .4
LTD2     TESTD    COMPD    .90  LARGE TEST SEPAPTE DOCTRINE
LTD2     DPERF 1    4.0        -5.0         0.0       -1.0       .4
LTD3     TESTD    COMPD    .95  LARGE TEST MODERATE DOCTRINE
LTD3     DPERF 1    4.0        -1.0        -.25       -.5        .4
FAPB     COMPD    FAIL     1.0  FAIL LARGE TEST DOCTRINE COMPARISON
BES1     COMPD    ADEQD    1.0  SUCCESS TOGETHER DO TRINE
BES1     DTIME 1    4.0         2.0         5.0        3.0       .5
BES1     RCOST 1 1STBES1    K 10.0   K 1.0
BES2     COMPD    ADEQD    1.0  SUCCESS SEPARATE DOCTRINE
BES2     DTIME 1    4.0         2.0         5.0        3.0       .5
BES2     RCOST 1 1STBES2    K 10.0   K 1.0
BES3     COMPD    ADEQD    1.0  SUCCESS MODERATE DOCTRINE
BES3     DTIME 1    4.0         2.0         5.0        3.0       .5
BES3     RCOST 1 1STBES3    K 10.0   K 1.0
FAILTRU  FAIL     BOOTHILL1.0   BURRIES UNWANTED FLOWS
BLCK     FAIL     BOOTHILL1.0   BLOCKS INITIATION OF BOOTHILL
BLCK     FILT3 1 -STOP
FAAP     ADEQD    FAIL     1.0  FAIL DOCTRINE GT 2 K
STOP     ADEQD    SUCCESS  1.0  SUCCESS DOCTRINE
STOP     FILT1 1                                                   2.0        50.
FDEC     FAIL     FAILP    1.0  FAIL R AND I DECT DIST
FDEC     FILT3 1 -STOP
ENDAPC
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START   1  2                    START POINT
BEGIN   2  2                    DIRECTORATE ORGANIZED , BEGIN DETECT PHASE
IMPSC   2  4                    TEST INITIATED IMPROVED RADAR
RADSC   2  4                    TEST INITIATED REGULAR RADAR
MITDI   5 -1               -1.0 SELECT MINIMUM DISTANCE IMPROVED ECM
MITDI   LINKIECO    BDOI    IECF    BDFI            FAII
MITDR   5 -1               -1.0 SELECT MINIMUM DISTANCE REGULAR RADAR, ECM
MITDR   LINKRECO    BDOR    RECF    BDFR            FAIR
BESTI   5 -1                1.0 SELECT THE BEST SYSTEM, WORST CONDITIONS  DECTION
BESTI   LINKBDOI    ENDI    BDFI    ENDD    BDOR    ENDR    BDFR    ENDB
BESTI   LINK        FAIS
BEGTK   3  2                    BEGIN TRACKING AND FIRING PHASE OF TEST
LASYS   2  4                    LASER TEST INITIATED
MTSYS   2  4                    MANUAL/RADAR TEST INITIATED
MITKL   5 -1               -1.0 SELECT MIN DISTANCE LASER ALTITUDE TEST
MITKL   LINKLTHA    TSPL    LTMA    TSML            FALI
MITKM   5 -1               -1.0 SELECT MIN DISTANCE MANUAL ALTITUDE
MITKM   LINKMTHA    TSPM    MTMA    TSMM            FAMI
LAWTP   3  2                    BEGIN WEATHER TEST LASER
MAWTP   3  2                    BEGIN WEATHER TEST MANUAL
MILTV   5 -1               -1.0 SELECT MIN WTHR DIST LASER
MILTV   LINKHVLA    BTLA    LVLA    BTLB            FAVL
MIMTV   5 -1               -1.0 SELECT MIN WTHR DIST MANUAL
MIMTV   LINKHVMA    BTMA    LVMA    BTMB            FAVM
BESTK   5 -1                1.0 SELECT MIN CONDITIONS BEST SYSTEM TRK/FIR PHASE
BESTK   LINKBTLA    MPE1    BTLB    MPE2    BTMA    MPE3    BTMB    MPE4
BESTK   LINK        FATK
TERMT   4  4                    END TRACK/FIRE PHASE OF TEST
BEDOC   4  2                    BEGIN DOCTRINE TEST
TOGDO   2  4                    RADAR TOGETHER DOCTRINE INITIATED
SEPDO   2  4                    RADAR SEPARATE DOCTRINE INITIATED ST
MODDO   2  4                    RADAR MODERATE TEST INITIATED ST
VRCOG   2  3                    VISUAL RECOGNITION REQUIRED
MXRDT   2  4                    EVALUATE RDR TOGETHER DOCTRINE
MXRDS   2  4                    EVALUATE RDR SEPARATE DOCTRINE
MXRDO   4  4                    EVALUATE RDR MODERATE DOCTRINE
TESTD   5 -2                1.0 SELECT BEST TWO DOCTRINES SMALL SCALE TEST
TESTD   LINKEVTD    LTD1    EVSD    LTD2    EVMD    LTD3            FADO
COMPD   5 -1                1.0 SELECT BEST DOCTRINE LARTE SCALE TEST
COMPD   LINKLTD1    BES1    LTD2    BES2    LTD3    BES3            FADB
ADEQD   3  4                    ADEQUATE DEFENSE AND PROTECTION CHECK
FAIL    3  6                    SINK FOR FAILURE FLOWS
SUCCESS 3  1                    SUCCESS
FAILP   3  1                    FAIL PROJECT
BOOTHILL2  1                    UNWANTED FLOWS
ENDNODE
1121      28450142337 500            1.0       1.0
FALCON - RUN NO 1 - OUTPUT OPTION 2 - NORMAL DATA
ENDARC
BEGTK   3  2   1
TERMT   4  4   2
ENDNODE
1121      52753515096 500            -1.       -1.
FALCON - RUN NO 1A - OUTPUT OPTION 2 - NORMAL DATA - NEGATIVE PERFORMANCE CP
ENDARC
BEGTK   3  2   1
TERMT   4  4   2

ENDNODE
11 1      52753515096 500            1.0       1.0
FALCON - RUN NO 1 - OUTPUT OPTION 0 - NORMAL DATA
ENDARC
FAILP   3  1  -1
ENDNODE
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1 31            96581  15                  1.0       1.0
FALCON- RUN NUMBER TWO -  UNIFORM DISTRIBUTIONS
ORGT     START   BEGID   1.0  OGANIZE TEST DIRECTORATE
ORGT     DTIME 1    2.0        .5          1.5
ORGT     DCOST 1    3.0        10.0        10.0       15.0
IMPR     BEGID   IMPSC   1.0  IMPROVED RADAR DETECTION
IMPR     DTIME 1    2.0        .5          1.5
IMPR     RCOST 1 1STIMPR    K 10.0   K 1.0
IMPR     DPERF 1    2.0        .5          35.0
RADR     BEGID   RADSC   1.0  BASIC RADAR DETECTION
RADR     DTIME 1    2.0        .5          1.5
RADR     RCOST 1 1STRADR    K 10.0   K 1.0
RADR     DPERF 1    2.0        .3          30.0
FADT     IMPSC   FAIL    1.0  FAIL TO DETECT GE 5 K IMPROVE
IECO     IMPSC   MIIDI   .90  ECM ON IMPROVED RADAR
IECO     FILT1 1                                                 5.0       50.0
IECO     RCOST 1 1SCIMPR    K .5     K 1.0
IECO     DPERF 1    2.0      -10.0      -.1
IECF     IMPSC   MIIDI   .95  ECM OFF IMPROVED RADAR
IECF     FILT1 1                                                 5.0       50.0
FADR     RADSC   FAIL    1.0  FAIL TO DETECT GE 5 K REGULAR
RECO     RADSC   MIIDR   .90   ECM ON REGULAR
RECO     FILT1 1                                                 5.0       50.0
RECO     RCOST 1 1SCRADR    K .5     K 1.0
RECO     DPERF 1    2.0      -11.0      -1.0
RECF     RADSC   MIIDR   .95  ECM OFF REGULAR
RECF     FILT1 1                                                 5.0       50.0
FAII     MIIDI   FAIL    1.0  FAIL COMPARISON RELIABILITY IMPROVED
BDOI     MIIDI   BESTI   1.0  SUCCESS ECM ON IMPROVED
BDFI     MIIDI   BESTI   1.0  SUCCESS ECM OFF IMPROVED
FAIR     MIIDR   FAIL    1.0  FAIL COMPARISON RELIABILITY REGULAR
BDOR     MIIDR   BESTI   1.0  SUCCESS ECM ON REGULAR
BDFR     MIIDR   BESTI   1.0  SUCCESS ECM OFF REGULAR
FAIS     BESTI   FAIL    1.0  FAIL COMPARISON DECTION
ENDI     BESTI   BEGTK   1.0  BEST VALUE IMPROVED SYSTEM
ENDC     BESTI   BEGTK   1.0  BEST VALUE IMPROVED ECM OFF
ENDR     BESTI   BEGTK   1.0  BEST VALUE REGULAR
ENDB     BESTI   BEGTK   1.0  BEST VALUE REGULAR ECM OFF
LAST     BEGTK   LASYS   1.0  LASER TRACK FIRE SYSTEM
LAST     DTIME 1    2.0        .5          3.0
LAST     RCOST 1 1STLAST    K 10.0   K 1.0
LAST     DPERF 1    2.0      -2.2       -.1
MANT     BEGTK   MTSYS   1.0  MANUAL TRACK FIRE SYSTEM
MANT     DTIME 1    2.0        .5          3.0
MANT     RCOST 1 1STMANT    K 10.0   K 1.0
MANT     DPERF 1    2.0      -4.2       -.3
FALT     LASYS   FAIL    1.0  FAIL LASER TRACK/FIRE GT 3 K
LTHA     LASYS   MITKL   .95  HIGH ALTITUDE EFFECT LASER
LTHA     FILT1 1                                                 3.0       50.0
LTHA     DPERF 1    2.0      -.9        -.5
LTMA     LASYS   MITKL   .90  MEDIUM ALTITUDE EFFECT LASER
LTMA     FILT1 1                                                 3.0       50.0
LTMA     DPERF 1    2.0      -.9         .5
LTMA     RCOST 1 1SCLAST    K .2     K 1.0
FAMR     MISYS   FAIL    1.0  FAIL MANUAL TRACK/FIRE GT 3 K
MTHA     MISYS   MITKM   .95  HIGH ALTITUDE EFFECT MANUAL
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MTHA   FILT1 1                                              3.0      50.0
MTHA   DPERF 1    2.0      -1.5      -.8
MTMA   MISYS   MITKM   .90  MEDIUM ALTITUDE EFFECT MANUAL
MTMA   FILT1 1                                              3.0      50.0
MTMA   DPERF 1    2.0      -1.2      .8
MTMA   RCOST 1 1SCMANT    K .2     K 1.0
FALI   MITKL   FAIL    1.0  FAIL LASER COMPARISON ALTITUDE
TSPL   MITKL   LAWTR   1.0  SUCCESS LASER HIGH ALTITUDE
TSML   MITKL   LAWTR   1.0  SUCCESS LASER MEDIUM ALTITUDE
FAMI   MITKM   FAIL    1.0  FAIL MANUAL COMPARISON ALTITUDE
TSPM   MITKM   MAWTR   1.0  SUCCESS MANUAL HIGH ALTITUDE
TSMM   MITKM   MAWTR   1.0  SUCCESS MANUAL MED ALTITUDE
HVLA   LAWTR   MILTV   .95  HIGH VISIBILITY LASER ECM OFF
HVLA   DPERF 1    2.0      -5.0      -1.0
LVLA   LAWTR   MILTV   .90  LOW VISIBILITY LASER ECM ON
LVLA   DPERF 1    2.0      -9.0      -2.0
LVLA   RCOST 1 1SCLAST    K .1     K 1.0
HVMA   MAWTR   MIMTV   .95  HIGH VISIBILITY MANUAL TRACK
HVMA   DPERF 1    2.0      -1.0      1.0
LVMA   MAWTR   MIMTV   .90  LOW VISIBILITY MANUAL
LVMA   DPERF 1    2.0      -5.0      -2.0
LVMA   RCOST 1 1SCMANT    K .1     K 1.0
FAVL   MILTV   FAIL    1.0  FAIL LASER VISIBILITY COMPARISON
BTLA   MILTV   BESTK   .95  SUCCESS HIGH VISIBILITY LASER
BTLB   MILTV   BESTK   .90  SUCCESS LOW VISIBILITY LASER
FAVM   MIMTV   FAIL    1.0  FAIL MANUAL VISIBILITY COMPARISON
BTMA   MIMTV   BESTK   .95  SUCCESS HIGH VISIBILITY MANUAL
BTMB   MIMTV   BESTK   .90  SUCCESS LOW VISIBILITY MANUAL
MPF1   BESTK   TERMT   1.0  SUCCESS LASER HIGH VISIBILITY ECM ON
MPF2   BESTK   TERMT   1.0  SUCCESS LASER LV ECM OFF
MPF3   BESTK   TERMT   1.0  SUCCESS MANUAL HIGH VISIBILITY , ALTITUDE
MPF4   BESTK   TERMT   1.0  SUCCESS MANUAL LOW VISIBILITY
FATK   BESTK   FAIL    1.0  FAIL TRACK COMPARISON
FSYS   TERMT   FAIL    1.0  FAIL TRACK/FIRE CYCLE GT 2 K
LODC   TERMT   BEDOC   1.0  BEGIN DOCTRINE TEST
LODC   FILT1 1                                              2.0      50.0
LODC   RPERF 1 1SPTERMT   K -1.0   K 1.0
LODC   DCOST 1    4.0      10.5      25.8      18.5      4.0
RTDO   BEDOC   TOGDO   1.0  RADAR TOGETER DOCTRINE
RTDO   DTIME 1    2.0      .8        3.0
RTDO   RCOST 1 1STRTDO    K 10.0   K 1.0
RTDO   DPERF 1    2.0      1.5       35.0
RSDO   BEDOC   SEPDO   1.0  RADAR SEPARATE DOCTRINE
RSDO   DTIME 1    2.0      .8        3.0
RSDO   RCOST 1 1STRSDO    K 10.0   K 1.0
RSDO   DPERF 1    2.0      5.0       39.0
RMDO   BEDOC   MODDO   1.0  MODERATE DOCTRINE
RMDO   DTIME 1    2.0      .8        3.0
RMDO   RCOST 1 1STRMDO    K 10.0   K 1.0
RMDO   DPERF 1    2.0      2.5       37.0
FATO   TOGDO   FAIL    1.0  FAIL TOGETHER DOCTRINE GT 5 K
WTDT   TOGDO   MXRDT   1.0  WEAPONS TIGHT TOGETHER DOCTRINE
WTDT   FILT1 1                                              5.0      50.0
WTDT   DPERF 1    2.0      -6.5      -3.5
WFDT   TOGDO   MXRDT   1.0  WEAPONS FREE TOGETHER DOCTRINE
WFDT   FILT1 1                                              5.0      50.0
WFDT   DPERF 1    2.0      -1.0      2.2
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FASO    SEPDO   FAIL    1.0  FAIL SEPARATE DOCGRINE GT 5 K
WTDS    SEPDO   MXRDS   1.0  WEAPONS TIGHT SEPARATE DOCTRINE
WTDS    FILT1 1                                              5.0        50.0
WTDS    DPERF 1    2.0       -8.5        -5.0
WFDS    SEPDO   MXRDS   1.0  WEAPONS FREE SEPARATE DOCTRINE
WFDS    FILT1 1                                              5.0        50.0
WFDS    DPERF 1    2.0        0.0         3.5
FAMO    MODDO   FAIL    1.0  FAIL MODERATE DOCTRINE
WTDM    MODDO   VRCOG   1.0  VISUAL RECOGNITION REQUIRED
WTDM    FILT1 1                                              5.0        50.0
WTDM    DPERF 1    2.0       -7.5        -4.0
WFDM    MODDO   MXRDO   1.0  WEAPONS FREE MODERATE DOCTRINE
WFDM    FILT1 1                                              5.0        50.0
WFDM    DPERF 1    2.0       -.5          3.0
FRCO    VRCOG   FAIL    1.0  FAIL VISUAL RECOG
FRCO    M       1 .1
VRCO    VRCOG   MXRDO   1.0  VISUAL RECOGNITION SUCCESSFUL
VRCO    M       1 .9
VRCO    DPERF 1    2.0       -7.5        -4.0
FAMT    MARDT   FAIL    1.0  FAIL DOCTRINE TOGT GT 2 K
EVTD    MARDT   TESTD   .95  EVALUATE DOCTRINE TOGETHER
EVTD    FILT1 1                                              2.0        50.0
EVTD    RPERF 1 1SPMXRDT   K -1.0   K 1.0     1SPMXRDT   K .5      K 1.0
FAMS    MARDS   FAIL    1.0  FAIL DOCTRINE TOGETHER GT 2 K
EVSD    MARDS   TESTD   .90  EVALUATE DOTRINE SEPARATE
EVSD    FILT1 1                                              2.0        50.0
EVSD    RPERF 1 1SPMXRDS   K -1.0   K 1.0     1SPMXRDS   K.5       K 1.0
FAMM    MARDO   FAIL    1.0  FAIL MODERATE DOCTRINE GT 2 K
EVMD    MARDO   TESTD   .95  EVALUATE MODERATE DOCTRINE
EVMD    FILT1 1                                              2.0        50.0
EVMD    RPERF 1 1SPMXRDO   K -1.0   K 1.0     1SPMXRDO   K .5      K 1.0
FADO    TESTD   FAIL    1.0  FAIL DOCTRINE COMPARISON SMALL TEST
LTD1    TESTD   COMPD   .95  LARGE TEST TOGETHER DOCTRINE
LTD1    DPERF 1    2.0       -2.0        -.5
LTD2    TESTD   COMPD   .90  LARGE TEST SEPARTE DOCTRINE
LTD2    DPERF 1    2.0       -5.0         0.0
LTD3    TESTD   COMPD   .95  LARGE TEST MODERATE DOCTRINE
LTD3    DPERF 1    2.0       -1.0        -.25
FADB    COMPD   FAIL    1.0  FAIL LARGE TEST DOCTRINE COMPARISON
BES1    COMPD   ADEQD   1.0  SUCCESS TOGETHER DO TRINE
BES1    DTIME 1    2.0        2.0         5.0
BES1    RCOST 1 1STBES1    K 10.0   K 1.0
BES2    COMPD   ADEQD   1.0  SUCCESS SEPARATE DOCTRINE
BES2    DTIME 1    2.0        2.0         5.0
BES2    RCOST 1 1STBES2    K 10.0   K 1.0
BES3    COMPD   ADEQD   1.0  SUCCESS MODERATE DOCTRINE
BES3    DTIME 1    2.0        2.0         5.0
BES3    RCOST 1 1STBES3    K 10.0   K 1.0
FAILTRN FAIL    BOOTHILL1.0  BURRIES UNWANTED FLOWS
BLCK    FAIL    BOOTHILL1.0  BLOCKS INITIATION OF BOOTHILL
BLCK    FILT3 1 -STOP
FAAP    ADEQD   FAIL    1.0  FAIL DOCTRINE GT 2 K
STOP    ADEQD   SUCCESS 1.0  SUCCESS DOCTRINE
STOP    FILT1 1                                              2.0        50.0
FDEC    FAIL    FAILP   1.0  FAIL R AND I DECT DIST
FDEC    FILT3 1 -STOP
ENDAPC
```

```
START    1  2                     START POINT
BEGID    2  2                     DIRECTORATE ORGANIZED , BEGIN DETECT PHASE
IMPSC    2  4                     TEST INITIATED IMPROVED RADAR
RADSC    2  4                     TEST INITIATED REGULAR RADAR
MITDT    5 -1               -1.0 SELECT MINIMUM DISTANCE IMPROVED ECM
MITDT    LINKIECO   BDOI    IECF    PDFI            FAII
MITDR    5 -1               -1.0 SELECT MINIMUM DISTANCE REGULAR RADAR, ECM
MITDR    LINKRECO   BDOR    RECF    BDFR            FAIR
BESTI    5 -1                1.0 SELECT THE BEST SYSTEM, WORST CONDITIONS  DECTION
BESTI    LINKBDOI   ENDI    BDFI    ENDD    PDOR    ENDR    BDFR    ENDB
BESTI    LINK       FAIS
BEGTK    3  2                     BEGIN TRACKING AND FIRING PHASE OF TEST
LASYS    2  4                     LASER TEST INITIATED
MTSYS    2  4                     MANUAL/RADAR TEST INITIATED
MITKL    5 -1               -1.0 SELECT MIN DISTANCE LASER ALTITUDE TEST
MITKL    LINKLTHA   TSPL    LTMA    TSML            FALI
MITKM    5 -1               -1.0 SELECT MIN DISTANCE MANUAL ALTITUDE
MITKM    LINKMTHA   TSPM    MTMA    TSMM            FAMI
LAWTP    3  2                     BEGIN WEATHER TEST LASER
MAWTP    3  2                     BEGIN WEATHER TEST MANUAL
MILTV    5 -1               -1.0 SELECT MIN WTHR DIST LASER
MILTV    LINKHVLA   BTLA    LVLA    BTLB            FAVL
MIMTV    5 -1               -1.0 SELECT MIN WTHR DIST MANUAL
MIMTV    LINKHVMA   BTMA    LVMA    BTMB            FAVM
BESTK    5 -1                1.0 SELECT MIN CONDITIONS BEST SYSTEM TRK/FIR PHASE
BESTK    LINKBTLA   MPE1    BTLB    MPE2    BTMA    MPE3    BTMB    MPE4
BESTK    LINK       FATK
TERMT    4  4                     END TRACK/FIRE PHASE OF TEST
BEDOC    4  2                     BEGIN DOCTRINE TEST
TOGDO    2  4                     RADAR TOGETHER DOCTRINE INITIATED
SEPDO    2  4                     RADAR SEPARATE DOCTRINE INITIATED ST
MODDO    2  4                     RADAR MODERATE TEST INITIATED ST
VRCOG    2  3                     VISUAL RECOGNITION REQUIRED
MXRDT    2  4                     EVALUATE RDR TOGETHER DOCTRINE
MXRDS    2  4                     EVALUATE RDR SEPARATE DOCTRINE
MXRDO    4  4                     EVALUATE RDR MODERATE DOCTRINE
TESTD    5 -2                1.0 SELECT BEST TWO DOCTRINES SMALL SCALE TEST
TESTD    LINKEVTD   LTD1    EVSD    LTD2    EVMD    LTD3            FADO
COMPD    5 -1                1.0 SELECT BEST DOCTRINE LARTE SCALE TEST
COMPD    LINKLTD1   RES1    LTD2    RES2    LTD3    RES3            FADB
ADEQP    3  4                     ADEQUATE DEFENSE AND PROTECTION CHECK
FAIL     3  6                     SINK FOR FAILURE FLOWS
SUCCESS  3  1                     SUCCESS
FAILP    3  1                     FAIL PROJECT
BOOTHILL 2  1                     UNWANTED FLOWS
ENDNODE
1121       28450142337 500              1.0       1.0
FALCON - RUN NO 2 - UNIFORM DATA
ENDARC
BEGTK    3  2   1
TERMT    4  4   2
ENDNODE
```

```
1 31            96581  10                 1.0       1.0
FALCON - RUN NO 3 - GAMMA, EXPONENTIAL,TRIANGULAR AND NORMAL DATA
ORGT     START    BEGID    1.0  OGANIZE TEST DIRECTORATE
ORGT     DTIME 1    2.0         .5         1.5
ORGT     DCOST 1    3.0         10.0       19.0       15.0
IMPR     BEGID    IMPSC    1.0  IMPROVED RADAR DETECTION
IMPR     DTIME 1    4.0         .5         1.5        1.0       .25
IMPR     RCOST 1 1STIMPR     K 20.0    K 1.0
IMPR     DPERF 1    6.0         .5         35.0       20.0      8.0
RADR     BEGID    RADSC    1.0  BASIC RADAR DETECTION
RADR     DTIME 1    4.0         .5         1.5        1.0       .25
RADR     RCOST 1 1STRADR     K 20.0    K 1.0
RADR     DPERF 1    6.0         .3         30.0       18.0      8.0
FADT     IMPSC    FAIL     1.0  FAIL TO DETECT GE 5 K IMPROVE
IECO     IMPSC    MIIDI    .90  ECM ON IMPROVED RADAR
IECO     FILT1 1                                                5.0       50.0
IECO     RCOST 1 1SCIMPR     K .5      K 1.0
IECO     DPERF 1    4.0        -10.0      -.1        -5.0       1.0
IECF     IMPSC    MIIDI    .95  ECM OFF IMPROVED RADAR
IECF     FILT1 1                                                5.0       50.0
FADR     RADSC    FAIL     1.0  FAIL TO DETECT GE 5 K REGULAR
RECO     RADSC    MIIDR    .90   ECM ON REGULAR
RECO     FILT1 1                                                5.0       50.0
RECO     RCOST 1 1SCRADR     K .5      K 1.0
RECO     DPERF 1    4.0        -12.5      -1.0       -5.0       2.5
RECF     RADSC    MIIDR    .95  ECM OFF REGULAR
RECF     FILT1 1                                                5.0       50.0
FATI     MIIDI    FAIL     1.0  FAIL COMPARISON RELIABILITY IMPROVED
BDOI     MIIDI    BESTI    1.0  SUCCESS ECM ON IMPROVED
BDFI     MIIDI    BESTI    1.0  SUCCESS ECM OFF IMPROVED
FATR     MIIDR    FAIL     1.0  FAIL COMPARISON RELIABILITY REGULAR
BDOR     MIIDR    BESTI    1.0  SUCCESS ECM ON REGULAR
BDFR     MIIDR    BESTI    1.0  SUCCESS ECM OFF REGULAR
FATS     BESTI    FAIL     1.0  FAIL COMPARISON DECTION
ENDI     BESTI    BEGTK    1.0  BEST VALUE IMPROVED SYSTEM
ENDD     BESTI    BEGTK    1.0  BEST VALUE IMPROVED ECM OFF
ENDR     BESTI    BEGTK    1.0  BEST VALUE REGULAR
ENDB     BESTI    BEGTK    1.0  BEST VALUE REGULAR ECM OFF
LAST     BEGTK    LASYS    1.0  LASER TRACK FIRE SYSTEM
LAST     DTIME 1    4.0         .5         3.0        1.2       1.8
LAST     RCOST 1 1STLAST     K 20.0    K 1.0
LAST     DPERF 1    4.0        -2.2       -.1        -1.0       .4
MANT     BEGTK    MISYS    1.0  MANUAL TRACK FIRE SYSTEM
MANT     DTIME 1    4.0         .5         3.0        1.2       1.8
MANT     RCOST 1 1STMANT     K 20.0    K 1.0
MANT     DPERF 1    4.0        -4.2       -.3        -1.1       .9
FALT     LASYS    FAIL     1.0  FAIL LASER TRACK/FIRE GT 3 K
LTHA     LASYS    MITKL    .95  HIGH ALTITUDE EFFECT LASER
LTHA     FILT1 1                                                3.0       50.0
LTHA     DPERF 1    4.0        -.9        -.5        -.75       .1
LTMA     LASYS    MITKL    .90  MEDIUM ALTITUDE EFFECT LASER
LTMA     FILT1 1                                                3.0       50.0
LTMA     DPERF 1    4.0        -.9         .5         0.0       .25
LTMA     RCOST 1 1SCLAST     K .2      K 1.0
FAMR     MISYS    FAIL     1.0  FAIL MANUAL TRACK/FIRE GT 3 K
MTHA     MISYS    MITKM    .95  HIGH ALTITUDE EFFECT MANUAL
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MTHA    FILT1 1                                                  3.0        50.0
MTHA    DPERF 1    4.0      -1.5      -.8       -1.0       .25
MTMA    MISYS   MITKM   .90  MEDIUM ALTITUDE EFFECT MANUAL
MTMA    FILT1 1                                                  3.0        50.0
MTMA    DPERF 1    4.0      -1.2       .8        0.0       .25
MTMA    RCOST 1 1SCMANT    K .2     K 1.0
FALI    MITKL   FAIL     1.0  FAIL LASER COMPARISON ALTITUDE
TSPL    MITKL   LAWTR    1.0  SUCCESS LASER HIGH ALTITUDE
TSML    MITKL   LAWTR    1.0  SUCCESS LASER MEDIUM ALTITUDE
FAMI    MITKM   FAIL     1.0  FAIL MANUAL COMPARISON ALTITUDE
TSPM    MITKM   MAWTR    1.0  SUCCESS MANUAL HIGH ALTITUDE
TSMM    MITKM   MAWTR    1.0  SUCCESS MANUAL MED ALTITUDE
HVLA    LAWTR   MILTV    .95  HIGH VISIBILITY LASER ECM OFF
HVLA    DPERF 1    4.0      -5.0      -1.0      -3.0       1.0
LVLA    LAWTR   MILTV    .90  LOW VISIBILITY LASER ECM ON
LVLA    DPERF 1    4.0      -9.0      -2.0      -4.0       2.0
LVLA    RCOST 1 1SCLAST    K .1     K 1.0
HVMA    MAWTR   MIMTV    .95  HIGH VISIBILITY MANUAL TRACK
HVMA    DPERF 1    4.0      -1.0       1.0       0.0       .25
LVMA    MAWTR   MIMTV    .90  LOW VISIBILITY MANUAL
LVMA    DPERF 1    4.0      -5.0      -2.0      -3.0       1.0
LVMA    RCOST 1 1SCMANT    K .1     K 1.0
FAVL    MILTV   FAIL     1.0  FAIL LASER VISIBILITY COMPARISON
RTLA    MILTV   BESTK    .95  SUCCESS HIGH VISIBILITY LASER
RTLB    MILTV   BESTK    .90  SUCCESS LOW VISIBILITY LASER
FAVM    MIMTV   FAIL     1.0  FAIL MANUAL VISIBILITY COMPARISON
RTMA    MIMTV   BESTK    .95  SUCCESS HIGH VISIBILITY MANUAL
RTMB    MIMTV   BESTK    .90  SUCCESS LOW VISIBILITY MANUAL
MPF1    BESTK   TERMT    1.0  SUCCESS LASER HIGH VISIBILITY ECM ON
MPF2    BESTK   TERMT    1.0  SUCCESS LASER LV ECM OFF
MPF3    BESTK   TERMT    1.0  SUCCESS MANUAL HIGH VISIBILITY , ALTITUDE
MPF4    BESTK   TERMT    1.0  SUCCESS MANUAL LOW VISIBILITY
FATK    BESTK   FAIL     1.0  FAIL TRACK COMPARISON
FSYS    TERMT   FAIL     1.0  FAIL TRACK/FIRE CYCLE GT 2 K
LOPC    TERMT   BEDOC    1.0  BEGIN DOCTRINE TEST
LOPC    FILT1 1                                                  2.0        50.0
LOPC    RPERF 1 1SPTERMT   K -1.0   K 1.0
LOPC    DCOST 1    4.0      10.5      25.8      18.5       4.0
RTDO    BEDOC   TOGDO    1.0  RADAR TOGETER DOCTRINE
RTDO    DTIME 1    4.0       .8        3.0       1.5        .1
RTDO    RCOST 1 1STRTDO    K 20.0   K 1.0
RTDO    DPERF 1    8.0       1.5      35.0      19.0       1.0
RSDO    BEDOC   SEPDO    1.0  RADAR SEPARATE DOCTRINE
RSDO    DTIME 1    4.0       .8        3.0       1.5        .1
RSDO    RCOST 1 1STRSDO    K 20.0   K 1.0
RSDO    DPERF 1    8.0       5.0      39.0      20.0       1.0
RMDO    BEDOC   MODDO    1.0  MODERATE DOCTRINE
RMDO    DTIME 1    4.0       .8        3.0       1.5        .1
RMDO    RCOST 1 1STRMDO    K 20.0   K 1.0
RMDO    DPERF 1    8.0       2.5      37.0      19.5       1.0
FATO    TOGDO   FAIL     1.0  FAIL TOGETHER DOCTRINE GT 5 K
WTDT    TOGDO   MXRDT    1.0  WEAPONS TIGHT TOGETHER DOCTRINE
WTDT    FILT1 1                                                  5.0        50.0
WTDT    DPERF 1    4.0      -6.5      -3.5      -5.0       1.0
WFDT    TOGDO   MXRDT    1.0  WEAPONS FREE TOGETHER DOCTRINE
WFDT    FILT1 1                                                  5.0        50.0
WFDT    DPERF 1    4.0      -1.0       2.2       0.0       1.0
```

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FASO     SEPDO    FAIL      1.0  FAIL SEPARATE DOCGRINE GT 5 K
WTDS     SEPDO    MXRDS     1.0  WEAPONS TIGHT SEPARATE DOCTRINE
WTDS     FILT1 1                                                      5.0          50.0
WTDS     DPERF 1     4.0        -8.5       -5.0      -6.0      1.0
WFDS     SEPDO    MXRDS     1.0  WEAPONS FREE SEPARATE DOCTRINE
WFDS     FILT1 1                                                      5.0          50.0
WFDS     DPERF 1     4.0         0.0        3.5       1.0      1.0
FAMO     MODDO    FAIL      1.0  FAIL MODERATE DOCTRINE
WTDM     MODDO    VRCOG     1.0  VISUAL RECOGNITION REQUIRED
WTDM     FILT1 1                                                      5.0          50.0
WTDM     DPERF 1     4.0        -7.5       -4.0      -5.5      1.0
WFDM     MODDO    MXRDO     1.0  WEAPONS FREE MODERATE DOCTRINE
WFDM     FILT1 1                                                      5.0          50.0
WFDM     DPERF 1     4.0        -.5         3.0        .5      1.0
FRCO     VRCOG    FAIL      1.0  FAIL VISUAL RECOG
FRCO     M       1 .1
VRCO     VRCOG    MXRDO     1.0  VISUAL RECOGNITION SUCCESSFUL
VRCO     M       1 .9
VRCO     DPERF 1     4.0        -7.5       -4.0      -5.5      1.0
FAMT     MARDT    FAIL      1.0  FAIL DOCTRINE TOGT GT 2 K
EVTD     MARDT    TESTD     .95  EVALUATE DOCTRINE TOGETHER
EVTD     FILT1 1                                                      2.0          50.0
EVTD     RPERF 1 1SPMXPDT    K -1.0    K 1.0     1SPMXRDT    K .5      K 1.0
FAMS     MARDS    FAIL      1.0  FAIL DOCTRINE TOGETHER GT 2 K
EVSD     MARDS    TESTD     .90  EVALUATE DOTRINE SEPARATE
EVSD     FILT1 1                                                      2.0          50.0
EVSD     RPERF 1 1SPMXPDS    K -1.0    K 1.0     1SPMXRDS    K.5       K 1.0
FAMM     MARDO    FAIL      1.0  FAIL MODERATE DOCTRINE GT 2 K
EVMD     MARDO    TESTD     .95  EVALUATE MODERATE DOCTRINE
EVMD     FILT1 1                                                      2.0          50.0
EVMD     RPERF 1 1SPMXPDO    K -1.0    K 1.0     1SPMXRDO    K .5      K 1.0
FADO     TESTD    FAIL      1.0  FAIL DOCTRINE COMPARISON SMALL TEST
LTD1     TESTD    COMPD     .95  LARGE TEST TOGETHER DOCTRINE
LTD1     DPERF 1     4.0        -2.0       -.5       -1.0       .4
LTD2     TESTD    COMPD     .90  LARGE TEST SEPARTE DOCTRINE
LTD2     DPERF 1     4.0        -3.0        0.0      -1.0       .4
LTD3     TESTD    COMPD     .95  LARGE TEST MODERATE DOCTRINE
LTD3     DPERF 1     4.0        -1.0       -.25      -.5        .4
FAD3     COMPD    FAIL      1.0  FAIL LARGE TEST DOCTRINE COMPARISON
BES1     COMPD    ADEQD     1.0  SUCCESS TOGETHER DO TRINE
BES1     DTIME 1     4.0         2.0        5.0       3.0       .5
BES1     RCOST 1 1STBES1     K 20.0    K 1.0
BES2     COMPD    ADEQD     1.0  SUCCESS SEPARATE DOCTRINE
BES2     DTIME 1     4.0         2.0        5.0       3.0       .5
BES2     RCOST 1 1STBES2     K 20.0    K 1.0
BES3     COMPD    ADEQD     1.0  SUCCESS MODERATE DOCTRINE
BES3     DTIME 1     4.0         2.0        5.0       3.0       .5
BES3     RCOST 1 1STBES3     K 20.0    K 1.0
FAILTRN  FAIL     BOOTHILL1.0  BURRIES UNWANTED FLOWS
BLCK     FAIL     BOOTHILL1.0  BLOCKS INITIATION OF BOOTHILL
BLCK     FILT3 1 -STOP
FAAP     ADEQD    FAIL      1.0  FAIL DOCTRINE GT 2 K
STOP     ADEQD    SUCCESS   1.0  SUCCESS DOCTRINE
STOP     FILT1 1                                                      2.0          50.0
FDEC     FAIL     FAILP     1.0  FAIL R AND I DECT DIST
FDEC     FILT3 1 -STOP
FNDAPC
```

```
START     1  2                  START POINT
BEGID     2  2                  DIRECTORATE ORGANIZED , BEGIN DETECT PHASE
IMPSC     2  4                  TEST INITIATED IMPROVED RADAR
RADSC     2  4                  TEST INITIATED REGULAR RADAR
MITDI     5 -1             -1.0 SELECT MINIMUM DISTANCE IMPROVED ECM
MITDI     LINKIECO    BDOI    IECF    BDFI            FAII
MITDR     5 -1             -1.0 SELECT MINIMUM DISTANCE REGULAR RADAR, ECM
MITDR     LINKRECO    BDOR    RECF    BDFR            FAIR
BESTI     5 -1              1.0 SELECT THE BEST SYSTEM, WORST CONDITIONS  DECTION
BESTI     LINKBDOI    ENDI    BDFI    ENDD    BDOR    ENDR    BDFR    ENDB
BESTI     LINK        FAIS
BEGTK     3  2                  BEGIN TRACKING AND FIRING PHASE OF TEST
LASYS     2  4                  LASER TEST INITIATED
MTSYS     2  4                  MANUAL/RADAR TEST INITIATED
MITKL     5 -1             -1.0 SELECT MIN DISTANCE LASER ALTITUDE TEST
MITKL     LINKLTHA    TSPL    LTMA    TSML            FALI
MITKM     5 -1             -1.0 SELECT MIN DISTANCE MANUAL ALTITUDE
MITKM     LINKMTHA    TSPM    MIMA    TSMM            FAMI
LAWTP     3  2                  BEGIN WEATHER TEST LASER
MAWTP     3  2                  BEGIN WEATHER TEST MANUAL
MILTV     5 -1             -1.0 SELECT MIN WTHR DIST LASER
MILTV     LINKHVLA    BTLA    LVLA    BTLB            FAVL
MIMTV     5 -1             -1.0 SELECT MIN WTHR DIST MANUAL
MIMTV     LINKHVMA    BTMA    LVMA    BTMB            FAVM
BESTK     5 -1              1.0 SELECT MIN CONDITIONS BEST SYSTEM TRK/FIR PHASE
BESTK     LINKBTLA    MPE1    BTLB    MPE2    BTMA    MPE3    BTMB    MPE4
BESTK     LINK        FATK
TERMT     4  4                  END TRACK/FIRE PHASE OF TEST
BEDOC     4  2                  BEGIN DOCTRINE TEST
TOGDO     2  4                  RADAR TOGETHER DOCTRINE INITIATED
SEPDO     2  4                  RADAR SEPARATE DOCTRINE INITIATED ST
MODDO     2  4                  RADAR MODERATE TEST INITIATED ST
VRCOG     2  3                  VISUAL RECOGNITION REQUIRED
MXRDT     2  4                  EVALUATE RDR TOGETHER DOCTRINE
MXRDS     2  4                  EVALUATE RDR SEPARATE DOCTRINE
MXRDO     4  4                  EVALUATE RDR MODERATE DOCTRINE
TESTD     5 -2              1.0 SELECT BEST TWO DOCTRINES SMALL SCALE TEST
TESTD     LINKEVTD    LTD1    EVSD    LTD2    EVMD    LTD3            FADO
COMPD     5 -1              1.0 SELECT BEST DOCTRINE LARTE SCALE TEST
COMPD     LINKLTD1    BES1    LTD2    BES2    LTD3    BES3            FADB
ADEQD     3  4                  ADEQUATE DEFENSE AND PROTECTION CHECK
FAIL      3  6                  SINK FOR FAILURE FLOWS
SUCCESS   3  1                  SUCCESS
FAILP     3  1                  FAIL PROJECT
POTHILL   2  1                  UNWANTED FLOWS
ENDNODE
1121      28450142537 500            1.0       1.0
FALCON - RUN NO 3 - GAMMA, EXPONENTIAL, TRIANGULAR AND NORMAL DATA
ENDARC
BEGTK     3  2  1
TERMT     4  4  2
ENDNODE
```

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1 31              96581  10                    1.0       1.0
FALCON - RUN NO 4 - GAMMA,EXPONENTIAL,NORMAL AND TRIANGULAR DATANEW MEANS
ORGT      START    BEGID    1.0  OGANIZE TEST DIRECTORATE
ORGT      DTIME 1    2.0         .5         1.5
ORGT      DCOST 1    8.0        10.0       19.0       14.5       1.0
IMPR      BEGID    IMPSC    1.0  IMPROVED RADAR DETECTION
IMPR      DTIME 1    4.0         .5         1.5        1.0        .25
IMPR      RCOST 1  1STIMPR     K 20.0    K 1.0
IMPR      DPERF 1    6.0         .5        35.0       10.0       8.0
RADR      BEGID    RADSC    1.0  BASIC RADAR DETECTION
RADR      DTIME 1    4.0         .5         1.5        1.0        .25
RADR      RCOST 1  1STRADR     K 20.0    K 1.0
RADR      DPERF 1    6.0         .3        30.0        9.0       8.0
FADT      IMPSC    FAIL     1.0  FAIL TO DETECT GE 5 K IMPROVE
IECO      IMPSC    MIIDI    .90  ECM ON IMPROVED RADAR
IECO      FILT1 1                                                5.0        50.0
IECO      RCOST 1  1SCIMPR     K .5      K 1.0
IECO      DPERF 1    4.0       -10.0       -.1        -5.0       1.0
IECF      IMPSC    MIIDI    .95  ECM OFF IMPROVED RADAR
IECF      FILT1 1                                                5.0        50.0
FADR      RADSC    FAIL     1.0  FAIL TO DETECT GE 5 K REGULAR
RECO      RADSC    MIIDR    .90   ECM ON REGULAR
RECO      FILT1 1                                                5.0        50.0
RECO      RCOST 1  1SCRADR     K .5      K 1.0
RECO      DPERF 1    4.0       -12.5       -1.0       -5.0       2.5
RECF      RADSC    MIIDR    .95  ECM OFF REGULAR
RECF      FILT1 1                                                5.0        50.0
FATI      MAIDI    FAIL     1.0  FAIL COMPARISON RELIABILITY IMPROVED
BDCI      MAIDI    BESTI    1.0  SUCCESS ECM ON IMPROVED
BDFI      MAIDI    BESTI    1.0  SUCCESS ECM OFF IMPROVED
FATR      MAIDR    FAIL     1.0  FAIL COMPARISON RELIABILITY REGULAR
BDCR      MAIDR    BESTI    1.0  SUCCESS ECM ON REGULAR
BDFR      MAIDR    BESTI    1.0  SUCCESS ECM OFF REGULAR
FATS      BESTI    FAIL     1.0  FAIL COMPARISON DECTION
FNDI      BESTI    BEGTK    1.0  BEST VALUE IMPROVED SYSTEM
FNDD      BESTI    BEGTK    1.0  BEST VALUE IMPROVED ECM OFF
FNDR      BESTI    BEGTK    1.0  BEST VALUE REGULAR
FNDB      BESTI    BEGTK    1.0  BEST VALUE REGULAR ECM OFF
LAST      BEGTK    LASYS    1.0  LASER TRACK FIRE SYSTEM
LAST      DTIME 1    4.0         .5         3.0        1.2       1.8
LAST      RCOST 1  1STLAST     K 20.0    K 1.0
LAST      DPERF 1    4.0        -2.2       -.1        -1.0        .4
MANT      BEGTK    MTSYS    1.0  MANUAL TRACK FIRE SYSTEM
MANT      DTIME 1    4.0         .5         3.0        1.2       1.8
MANT      RCOST 1  1STMANT     K 20.0    K 1.0
MANT      DPERF 1    4.0        -4.2       -.3        -1.1        .9
FALT      LASYS    FAIL     1.0  FAIL LASER TRACK/FIRE GT 3 K
LTHA      LASYS    MITKL    .95  HIGH ALTITUDE EFFECT LASER
LTHA      FILT1 1                                                3.0        50.0
LTHA      DPERF 1    4.0        -.9        -.5        -.75        .1
LTMA      LASYS    MITKL    .90  MEDIUM ALTITUDE EFFECT LASER
LTMA      FILT1 1                                                3.0        50.0
LTMA      DPERF 1    4.0        -.9         .5         0.0        .25
LTMA      RCOST 1  1SCLAST     K .2      K 1.0
FAMR      MISYS    FAIL     1.0  FAIL MANUAL TRACK/FIRE GT 3 K
MTHA      MISYS    MITKM    .95  HIGH ALTITUDE EFFECT MANUAL
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FASD    SEPDO   FAIL     1.0  FAIL SEPARATE DOCGRINE GT 5 K
WTDS    SEPDO   MXRDS    1.0  WEAPONS TIGHT SEPARATE DOCTRINE
WTDS    FILT1 1                                                 5.0        50.0
WTDS    DPERF 1    4.0        -8.5       -5.0      -6.0        1.0
WFDS    SEPDO   MXRDS    1.0  WEAPONS FREE SEPARATE DOCTRINE
WFDS    FILT1 1                                                 5.0        50.0
WFDS    DPERF 1    4.0        0.0        3.5        1.0        1.0
FAMO    MODDO   FAIL     1.0  FAIL MODERATE DOCTRINE
WTDM    MODDO   VRCOG    1.0  VISUAL RECOGNITION REQUIRED
WTDM    FILT1 1                                                 5.0        50.0
WTDM    DPERF 1    4.0        -7.5       -4.0      -5.5        1.0
WFDM    MODDO   MXRDO    1.0  WEAPONS FREE MODERATE DOCTRINE
WFDM    FILT1 1                                                 5.0        50.0
WFDM    DPERF 1    4.0        -.5        3.0        .5         1.0
FRCO    VRCOG   FAIL     1.0  FAIL VISUAL RECOG
FRCO    M      1 .1
VRCO    VRCOG   MXRDO    1.0  VISUAL RECOGNITION SUCCESSFUL
VRCO    M      1 .9
VRCO    DPERF 1    4.0        -7.5       -4.0      -5.5        1.0
FAMT    MARDT   FAIL     1.0  FAIL DOCTRINE TOGT GT 2 K
EVTD    MARDT   TESTD    .95  EVALUATE DOCTRINE TOGETHER
EVTD    FILT1 1                                                 2.0        50.0
EVTD    RPERF 1 1SPMXRDT   K -1.0   K 1.0     1SPMXRDT   K .5      K 1.0
FAMS    MARDS   FAIL     1.0  FAIL DOCTRINE TOGETHER GT 2 K
EVSD    MARDS   TESTD    .90  EVALUATE DOTRINE SEPARATE
EVSD    FILT1 1                                                 2.0        50.0
EVSD    RPERF 1 1SPMXRDS   K -1.0   K 1.0     1SPMXRDS   K.5       K 1.0
FAMM    MARDO   FAIL     1.0  FAIL MODERATE DOCTRINE GT 2 K
EVMD    MARDO   TESTD    .95  EVALUATE MODERATE DOCTRINE
EVMD    FILT1 1                                                 2.0        50.0
EVMD    RPERF 1 1SPMXRDO   K -1.0   K 1.0     1SPMXRDO   K .5      K 1.0
FAPD    TESTD   FAIL     1.0  FAIL DOCTRINE COMPARISON SMALL TEST
LTD1    TESTD   COMPD    .95  LARGE TEST TOGETHER DOCTRINE
LTD1    DPERF 1    4.0        -2.0       -.5       -1.0        .4
LTD2    TESTD   COMPD    .90  LARGE TEST SEPARTE DOCTRINE
LTD2    DPERF 1    4.0        -3.0        0.0      -1.0        .4
LTD3    TESTD   COMPD    .95  LARGE TEST MODERATE DOCTRINE
LTD3    DPERF 1    4.0        -1.0       -.25      -.5         .4
FADR    COMPD   FAIL     1.0  FAIL LARGE TEST DOCTRINE COMPARISON
RES1    COMPD   ADEQD    1.0  SUCCESS TOGETHER DO TRINE
RES1    DTIME 1    4.0        2.0        5.0        3.0        .5
RES1    RCOST 1 1STRES1    K 20.0   K 1.0
RES2    COMPD   ADEQD    1.0  SUCCESS SEPARATE DOCTRINE
RES2    DTIME 1    4.0        2.0        5.0        3.0        .5
RES2    RCOST 1 1STRES2    K 20.0   K 1.0
RES3    COMPD   ADEQD    1.0  SUCCESS MODERATE DOCTRINE
RES3    DTIME 1    4.0        2.0        5.0        3.0        .5
RES3    RCOST 1 1STRES3    K 20.0   K 1.0
FAILTRN FAIL    BOOTHILL1.0   BURRIES UNWANTED FLOWS
BLCK    FAIL    BOOTHILL1.0   BLOCKS INITIATION OF BOOTHILL
BLCK    FILT3 1 -STOP
FADP    ADEQD   FAIL     1.0  FAIL DOCTRINE GT 2 K
STOP    ADEQD   SUCCESS  1.0  SUCCESS DOCTRINE
STOP    FILT1 1                                                 2.0        50.0
FDEC    FAIL    FAILP    1.0  FAIL R AND I DECT DIST
FDEC    FILT3 1 -STOP
ENDARC
```

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MTHA    FILT1 1                                                3.0        50.0
MTHA    DPERF 1     4.0       -1.5       -.8       -1.0       .25
MTMA    MISYS   MITKM   .90  MEDIUM ALTITUDE EFFECT MANUAL
MTMA    FILT1 1                                                3.0        50.0
MTMA    DPERF 1     4.0       -1.2        .8        0.0       .25
MTMA    RCOST 1 1SCMANT     K .2      K 1.0
FALI    MITKL   FAIL     1.0  FAIL LASER COMPARISON ALTITUDE
TSPL    MITKL   LAWTR    1.0  SUCCESS LASER HIGH ALTITUDE
TSML    MITKL   LAWTR    1.0  SUCCESS LASER MEDIUM ALTITUDE
FAMI    MITKM   FAIL     1.0  FAIL MANUAL COMPARISON ALTITUDE
TSPM    MITKM   MAWTR    1.0  SUCCESS MANUAL HIGH ALTITUDE
TSMM    MITKM   MAWTR    1.0  SUCCESS MANUAL MED ALTITUDE
HVLA    LAWTR   MILTV    .95  HIGH VISIBILITY LASER ECM OFF
HVLA    DPERF 1     4.0       -5.0       -1.0       -3.0      1.0
LVLA    LAWTR   MILTV    .90  LOW VISIBILITY LASER ECM ON
LVLA    DPERF 1     4.0       -9.0       -2.0       -4.0      2.0
LVLA    RCOST 1 1SCLAST     K .1      K 1.0
HVMA    MAWTR   MIMTV    .95  HIGH VISIBILITY MANUAL TRACK
HVMA    DPERF 1     4.0       -1.0        1.0        0.0      .25
LVMA    MAWTR   MIMTV    .90  LOW VISIBILITY MANUAL
LVMA    DPERF 1     4.0       -5.0       -2.0       -3.0      1.0
LVMA    RCOST 1 1SCMANT     K .1      K 1.0
FAVL    MILTV   FAIL     1.0  FAIL LASER VISIBILITY COMPARISON
BTLA    MILTV   BESTK    .95  SUCCESS HIGH VISIBILITY LASER
BTLB    MILTV   BESTK    .90  SUCCESS LOW VISIBILITY LASER
FAVM    MIMTV   FAIL     1.0  FAIL MANUAL VISIBILITY COMPARISON
BTMA    MIMTV   BESTK    .95  SUCCESS HIGH VISIBILITY MANUAL
BTMB    MIMTV   BESTK    .90  SUCCESS LOW VISIBILITY MANUAL
MPF1    BESTK   TERMT    1.0  SUCCESS LASER HIGH VISIBILITY ECM ON
MPF2    BESTK   TERMT    1.0  SUCCESS LASER LV ECM OFF
MPF3    BESTK   TERMT    1.0  SUCCESS MANUAL HIGH VISIBILITY , ALTITUDE
MPF4    BESTK   TERMT    1.0  SUCCESS MANUAL LOW VISIBILITY
FATK    BESTK   FAIL     1.0  FAIL TRACK COMPARISON
FSYS    TERMT   FAIL     1.0  FAIL TRACK/FIRE CYCLE GT 2 K
LODC    TERMT   BEDOC    1.0  BEGIN DOCTRINE TEST
LODC    FILT1 1                                                2.0        50.0
LODC    RPERF 1 1SPTERMT    K -1.0    K 1.0
LODC    DCOST 1     8.0       10.5       25.9       18.5      1.0
RTDO    BEDOC   TOGDO    1.0  RADAR TOGETHER DOCTRINE
RTDO    DTIME 1     4.0        .8         3.0        1.5       .1
RTDO    RCOST 1 1STRTDO     K 20.0    K 1.0
RTDO    DPERF 1     8.0        1.5       35.0       10.0      1.0
RSDO    BEDOC   SEPDO    1.0  RADAR SEPARATE DOCTRINE
RSDO    DTIME 1     4.0        .8         3.0        1.5       .1
RSDO    RCOST 1 1STRSDO     K 20.0    K 1.0
RSDO    DPERF 1     8.0        5.0       39.0       11.0      1.0
RMDO    BEDOC   MODDO    1.0  MODERATE DOCTRINE
RMDO    DTIME 1     4.0        .8         3.0        1.5       .1
RMDO    RCOST 1 1STRMDO     K 20.0    K 1.0
RMDO    DPERF 1     8.0        2.5       37.0       12.5      1.0
FATC    TOGDO   FAIL     1.0  FAIL TOGETHER DOCTRINE GT 5 K
WTDT    TOGDO   MXRDT    1.0  WEAPONS TIGHT TOGETHER DOCTRINE
WTDT    FILT1 1                                                5.0        50.0
WTDT    DPERF 1     4.0       -6.5       -3.5       -5.0      1.0
WFDT    TOGDO   MXRDT    1.0  WEAPONS FREE TOGETHER DOCTRINE
WFDT    FILT1 1                                                5.0        50.0
WFDT    DPERF 1     4.0       -1.0        2.2        0.0      1.0
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```
START    1  2                  START POINT
BEGIN    2  2                  DIRECTORATE ORGANIZED , BEGIN DETECT PHASE
IMPSC    2  4                  TEST INITIATED IMPROVED RADAR
RADSC    2  4                  TEST INITIATED REGULAR RADAR
MITDT    5 -1              -1.0 SELECT MINIMUM DISTANCE IMPROVED ECM
MITDT    LINKIECO    BDOI   IECF    BDFI            FAII
MITDR    5 -1              -1.0 SELECT MINIMUM DISTANCE REGULAR RADAR, ECM
MITDR    LINKRECO    BDOR   RECF    BDFR            FAIR
BESTI    5 -1               1.0 SELECT THE BEST SYSTEM, WORST CONDITIONS  DECTION
BESTI    LINKBDOI    ENDI   BDFI    ENDD    BDOR    ENDR    BDFR    ENDB
BESTI    LINK        FAIS
BEGTK    3  2                  BEGIN TRACKING AND FIRING PHASE OF TEST
LASYS    2  4                  LASER TEST INITIATED
MTSYS    2  4                  MANUAL/RADAR TEST INITIATED
MITKL    5 -1              -1.0 SELECT MIN DISTANCE LASER ALTITUDE TEST
MITKL    LINKLTHA    TSPL   LTMA    TSML            FALI
MITKM    5 -1              -1.0 SELECT MIN DISTANCE MANUAL ALTITUDE
MITKM    LINKMTHA    TSPM   MTMA    TSMM            FAMI
LAWTR    3  2                  BEGIN WEATHER TEST LASER
MAWTR    3  2                  BEGIN WEATHER TEST MANUAL
MILTV    5 -1              -1.0 SELECT MIN WTHR DIST LASER
MILTV    LINKHVLA    BTLA   LVLA    BTLB            FAVL
MIMTV    5 -1              -1.0 SELECT MIN WTHR DIST MANUAL
MIMTV    LINKHVMA    BTMA   LVMA    BTMB            FAVM
BESTK    5 -1               1.0 SELECT MIN CONDITIONS BEST SYSTEM TRK/FIR PHASE
BESTK    LINKBTLA    MPE1   BTLB    MPE2    BTMA    MPE3    BTMB    MPE4
BESTK    LINK        FATK
TERMT    4  4                  END TRACK/FIRE PHASE OF TEST
BEDOC    4  2                  BEGIN DOCTRINE TEST
TOGDO    2  4                  RADAR TOGETHER DOCTRINE INITIATED
SEPDO    2  4                  RADAR SEPARATE DOCTRINE INITIATED ST
MODDO    2  4                  RADAR MODERATE TEST INITIATED ST
VRCOG    2  3                  VISUAL RECOGNITION REQUIRED
MXRDT    2  4                  EVALUATE RDR TOGETHER DOCTRINE
MXRDS    2  4                  EVALUATE RDR SEPARATE DOCTRINE
MXRDO    4  4                  EVALUATE RDR MODERATE DOCTRINE
TESTD    5 -2               1.0 SELECT BEST TWO DOCTRINES SMALL SCALE TEST
TESTD    LINKEVTD    LTD1   EVSD    LTD2    EVMD    LTD3            FADO
COMPD    5 -1               1.0 SELECT BEST DOCTRINE LARTE SCALE TEST
COMPD    LINKLTD1    BES1   LTD2    BES2    LTD3    BES3            FADB
ADEQD    3  4                  ADEQUATE DEFENSE AND PROTECTION CHECK
FAIL     3  6                  SINK FOR FAILURE FLOWS
SUCCESS  3  1                  SUCCESS
FAILP    3  1                  FAIL PROJECT
BOOTHILL2   1                  UNWANTED FLOWS
ENDNODE
1121      28450142337 500             1.0         1.0
FALCON - RUN NO 4 - GAMMA,EXPONENTIAL,NORMAL AND TRIANGULAR DATA, NEW MEAN
ENDARC
BEGTK    3   2    1
TERMT    4   4    2
ENDNODE
```

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